VLCounter: Text-aware Visual Representation for Zero-Shot Object Counting

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Abstract

Zero-Shot Object Counting (ZSOC) aims to count referred instances of arbitrary classes in a query image without human-annotated exemplars. To deal with ZSOC, preceding studies proposed a **two-stage** pipeline: discovering exemplars and counting. However, there remains a challenge of vulnerability to error propagation of the sequentially designed two-stage process. In this work, we propose an **one-stage** baseline, Visual-Language Baseline (VLBase), exploring the implicit association of the semantic-patch embeddings of CLIP. Subsequently, we extend the VLBase to Visual-language Counter (VLCounter) by incorporating three modules devised to tailor VLBase for object counting. First, we introduce Semantic-conditioned Prompt Tuning (SPT) within the image encoder to acquire target-highlighted representations. Second, Learnable Affine Transformation (LAT) is employed to translate the semantic-patch similarity map to be appropriate for the counting task. Lastly, we transfer the layerwisely encoded features to the decoder through Segment-aware Skip Connection (SaSC) to keep the generalization capability for unseen classes. Through extensive experiments on FSC147, CARPK, and PUCPR+, we demonstrate the benefits of our end-to-end framework, VLCounter. Code is available at https://github.com/seunggu0305/VLCounter

1 Introduction

Object counting, which was initially studied for specific targets, e.g., crowds (**?**), cells (**?**), animals (**?**), and cars (**?**), has shown that the number of objects can be counted even within a dense image. Furthermore, recent works have shown significant advances to infer the number of arbitrary objects with several human-annotated exemplar patches. However, such a strong prerequisite that every cumbersome guidance must be equipped is undoubtedly the main challenge to overcome to grant applicability to object counting methods. In this context, Zero-Shot Object Counting (ZSOC) was proposed to mitigate the need for human labor.

Current ZSOC approaches commonly adopt a two-stage pipeline as illustrated in Fig. 1. These works primarily focus on identifying exemplar patches within the image and subsequently adopt the counting framework from the literature of few-shot object counting (**??**). To identify the exemplar

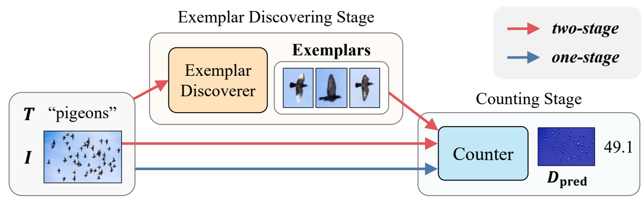

Figure 1: Comparison between two-stage pipeline and one-stage pipeline (ours). The two-stage pipeline requires training the exemplar discoverer (orange) before the counter (blue), along with the need for an extra training dataset to optimize the discoverer. In contrast, our one-stage pipeline is designed to be simpler and does not necessitate any additional data or training stage.

patches, RepRPN (**?**) considered the repetition score to detect object patches that frequently appear within the image. Requirement for counting the desired classes over frequent ones, ZSC (**?**) utilized the class names to enable the class specification. They localize exemplars by identifying the k-nearest neighbors of the class name embeddings among randomly cropped patches. Despite their progress, the potential localization error propagation in the two-stage training pipeline (**?**) is an untapped problem in ZSOC frameworks. Indeed, they utilized additional datasets to train decent exemplar discovery networks.

This paper pursues a simplified zero-shot object counting framework. We instantiate an end-to-end ZSOC counter namely Visual-Language Baseline (VLBase), which consists of a CLIP (**?**) encoder and counting decoder. By leveraging the embedding space of CLIP which enables the implicit association of the semantic and patch embeddings to localize the target object (**??**), VLBase eliminates the need for an exemplar discovery process.

Additionally, we introduce VLCounter which is built upon VLBase by incorporating three modules devised to tailor VLBase for object counting. First, we propose Semantic-conditioned Prompt Tuning (SPT) which extends the visual prompt tuning (VPT) to efficiently finetune CLIP for the counting task. Instead of utilizing naïve learnable prompts, SPT employs conditioning via semantic embedding to generate patch embeddings that emphasize the region of inter-

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est. Subsequently, based on our observation that the similarity maps between patch embeddings obtained using SPT and semantic embeddings already provide a decent approximation of object locations, we employ simple Learnable Affine Transformation (LAT) to adjust only the finer details. Finally, to equip the decoder with the generalization capability and provide rich clues, we exploit intermediate features across different encoding layers of CLIP through Segment-aware Skip Connections (SaSC). With all components combined, our simple end-to-end one-stage framework records new state-of-the-art results on the FSC147 (**?**) dataset validating its superiority over the previous ZSOC methods. Moreover, we provide additional evidence of cross-dataset generalization by evaluating performance on the car counting dataset CARPK (**?**).

Our contributions are three-fold:

- We instantiate an end-to-end baseline for ZSOC, VL-Base, by exploiting the vision-language association capability of CLIP.
- We propose a VLCounter consisting of SPT, LAT, and SaSC that allows the model to utilize the generalization capability of CLIP in a counting-specific manner.
- Our experiments on FSC147 and cross-dataset validation verify the effectiveness of VLCounter.

2 Related Works

2.1 Object Counting

Class-specific Object Counting focuses on quantifying specific class samples, e.g., crowds (**????**), cars (**??**), animals (**?**), and cells (**?**). Most works fall into two main categories each employing detection (**???**) or regression (**????**) mechanism to measure the number of instances. The former predicts the bounding box for every instance using an object detector, whereas the latter predicts the density distribution of the image instead, thereby being recognized as a more robust stream against partially occluded objects (**?**).

Few-shot Object Counting To overcome the lack of generality of being constrained to a specific class, Generic Matching Network (GMN) (**?**) first formalized class-agnostic object counting to count the desired objects provided by the human-annotated exemplar patches. They introduced a two-stream architecture to encode each image and exemplar to handle the difference in their resolution. Following them, CFOCNet (**?**) and BMNet (**?**) also adopted and enhanced the two-stream approach by adding a layer-wise matching procedure and bilinear similarity metric. Other works adhere to single-stream architecture. To be specific, FamNet (**?**) and RCAC (**?**) use ROI pooling after feature extraction to obtain exemplar prototypes. However, the aforementioned studies suffer from the limitation that every inference requires human-annotated exemplars.

Zero-shot Object Counting has been proposed by RepRPN (**?**) to discard the duty of annotating target exemplars for counting. To be specific, they trained the region proposal network (RPN) to capture the patches containing the most frequently appeared objects to replace human-annotated exemplars. Then, to further grant more applicability to exemplar-free object counter, ZSC (**?**) presented a method that takes guidance from semantic information. By matching semantic information to randomly generated patches, they sampled the most semantically relevant patches to obtain target exemplars. Our work shares the goal with ZSC in that we aim to train the counter that can count user-specified classes with only class names. Yet, as mentioned methods adopt a two-stage pipeline that is prone to error propagation, we focus on mitigating such issues by proposing an end-to-end framework that localizes and counts at once.

2.2 Prompt Tuning

Prompt tuning is a popular strategy to adapt pre-trained large models for downstream tasks due to its efficiency compared to conventional fine-tuning methods (**????**). Whereas fine-tuning updates all parameters, prompt tuning freezes the pre-trained large models and introduces only a small set of learnable prompts to optimize (**??**). Following these works, we utilize prompt tuning to efficiently exploit the quality of the visual-language understanding capability of pre-trained CLIP. Yet, our work differs in using semantic information from the semantic embeddings to condition the prompts in the visual encoder to concentrate more on specification-relevant information.

3 Preliminaries

3.1 Problem Formulation: ZSOC

ZSOC aims to predict the density map $D \in \mathbb{R}^{H \times W \times 1}$ for image $I \in \mathbb{R}^{H \times W \times 3}$ that belongs to unseen classes C^u ($f : (I, C^u) \mapsto D$) without any visual exemplar clues. In the training stage, the model is trained with $\mathcal{D}_{\text{train}} = \{(I_i, C_i^s, D_i)\}_{i=1}^{i=\mathbb{N}}$ where C_i^s denotes the seen class names during training. Then in the testing stage, the model is to yield a density map for $\mathcal{D}_{\text{test}} = \{(I_i, C_i^u, D_i)\}_{i=\mathbb{N}+1}^{i=\mathbb{M}}$, where $C^s \cap C^u = \varnothing$.

3.2 Overview of CLIP

This section introduces the underlying motivation behind our proposed method. CLIP is composed of two encoders: an image encoder $\phi_V(\cdot)$ and a text encoder $\phi_T(\cdot)$. The text encoder takes prompted class name t e.g., *A photo of [$kiwi$]* and produces a semantic embedding $\mathcal{T} \in \mathbb{R}^{1 \times d}$ where d represents an embedding dimension. The image encoder takes a learnable class token $[cls]$ along with embedded patch sequences V as inputs and encodes global and local semantics in the class token $[cls]$ and patch tokens $\mathcal{V}$ respectively. Note that $V = [v_1, v_2, ..., v_N] \in \mathbb{R}^{N \times (P^2 \cdot d)}$ where N is the number of embedded patches, and $(P \cdot P)$ is the resolution of each patch. Formally, this process can be expressed as follows:

$$\mathcal{T} = \phi_T(t); \qquad [\,[cls], \mathcal{V}\,] = \phi_V([\,[cls], V\,]). \tag{1}$$

These encoders are trained collaboratively to map $\mathcal{T}$ and $[cls]$ into a shared representation space.

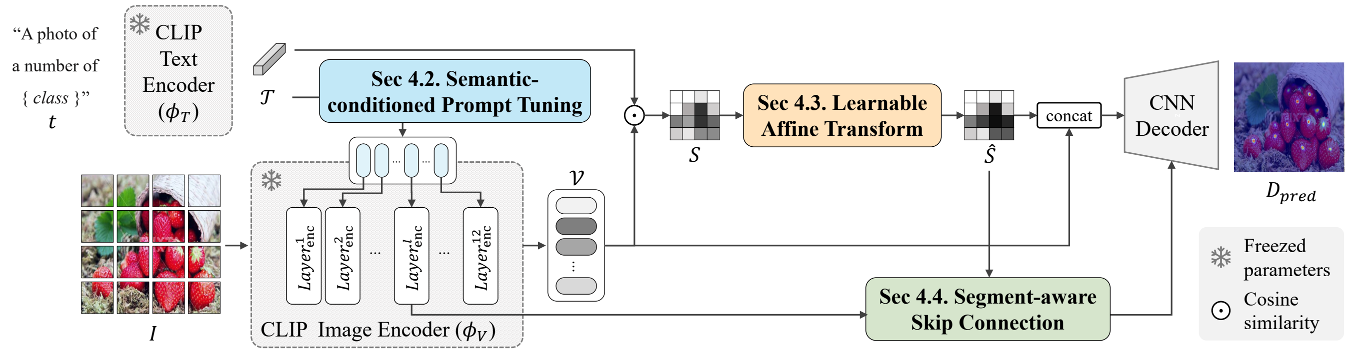

Figure 2: Overview of VLBase and VLCounter: each without and with colored components. The end-to-end baseline, VLBase, employs CLIP encoders to extract both image and text embeddings. Then, the decoder processes the image-text similarity map along with visual embeddings to count the number of specified objects. With three colored modules, VLCounter leverages the generalization capability of VLBase to be tailored for object counting.

Recently, there exist studies suggesting the implicit localization capability of CLIP, where each patch embedding preserves local image semantics (**??**). And this property, coupled with the powerful image-text joint embedding space of CLIP, has provided a clear motivation for utilizing CLIP as a robust tool for zero-shot segmentation (localization). (**???**). Taking similar inspiration yet focused on object counting, we aim to leverage the implicit localization capability of CLIP to achieve precise and efficient object counting in an end-to-end manner.

4 Visual-Language Counter: End-to-End Framework for Zero-Shot Object Counting

This section presents Visual-Language Counter (VLCounter), an efficient end-to-end ZSOC framework. We first establish a baseline model referred to as Vision-Language Baseline (VLBase), which exploits the visual-language localization capacity of CLIP in Sec. 4.1. Then, we bring three improvements on top of VLBase to introduce VLCounter. Specifically, we emphasize the regions of interests (Sec. 4.2), learn task-specific visual-language similarity (Sec. 4.3), and exploit semantic-relevant information across the multi-level representations (Sec. 4.4). The overall architectures of the two models are illustrated in Fig. 2.

4.1 Visual-Language Baseline

VLBase is a standalone baseline, eliminating the need for few-shot counting techniques that previous ZSOC approaches heavily rely on. Given input query image I and class name C, VLBase obtains patch embedding $\mathcal{V}$ and semantic embedding $\mathcal{T}$ using CLIP encoders $\phi_V(\cdot)$ and $\phi_T(\cdot)$, respectively. By calculating the cosine similarity between $\mathcal{T}$ and $\mathcal{V}$, the similarity map $S \in \mathbb{R}^{H\times W}$ is yielded:

$$S_{ij}(\mathcal{V},\mathcal{T}) = \frac{v_{ij}\mathcal{T}^\top}{||v_{ij}||||\mathcal{T}||}, \tag{2}$$

where S_{ij} corresponds to the value at position (i,j) in matrix S and v_{ij} represents the embedding at position (i,j) of 2D-reshaped $\mathcal{V}$.

As mentioned in prior studies (**??**), we observed that the similarity map between CLIP-encoded semantic and patch embeddings provides an adequate indication of the degree of semantic similarity between the patch and semantic embedding. We find that this similarity map is a decent clue for a decoder to localize the target objects. Consequently, the CNN-based counting decoder predicts the density map D_{pred} by utilizing features of $\mathcal{V}$ and S:

$$D_{\text{pred}} = \phi_{\text{decoder}}([\mathcal{V}, S]), \tag{3}$$

where $[\cdot,\cdot]$ denotes channel-wise concatenation. Finally, the object count prediction is derived by summing all values in D_{pred}.

Counting Loss For training, we adopt a conventional MSE loss:

$$\mathcal{L}_{\text{count}} = ||D_{\text{pred}} - D_{\text{gt}}||_2^2, \tag{4}$$

where D_{gt} denotes the ground truth density map.

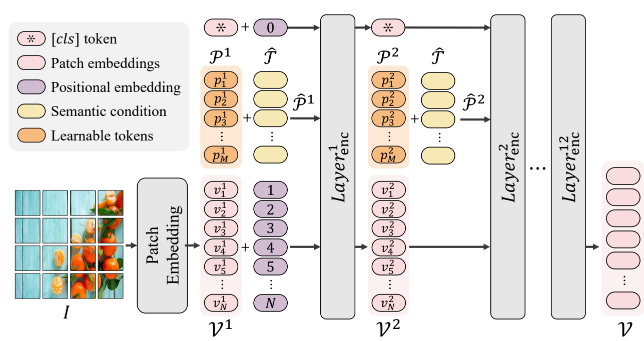

Figure 3: Illustration for Semantic-conditioned Prompt Tuning (SPT). In addition to learnable visual prompts (orange) in the image encoder, text features (yellow) are integrated to specify the desired semantics.

4.2 Semantic-conditioned Prompt Tuning (SPT)

To grant task-specificity to the CLIP image encoder without sacrificing its generalization capability, a straightforward approach is to employ visual prompt tuning (VPT) (**?**). However, the naïve VPT, which simply concatenates a few learnable tokens to the input sequence of each encoding layer does not take the semantic information into account. Hence, we introduce Semantic-conditioned Prompt Tuning (SPT), which utilizes semantic information along with the learnable tokens to assist the image encoder to extract target-semantic-highlighted visual features.

Specifically, as illustrated in Fig. 3, SPT has new learnable tokens for each encoding layer. Learnable tokens for l^{th} layer are defined as $\mathcal{P}^l = [p_1^l, p_2^l, ..., p_M^l]$ where the number of learnable tokens is denoted as M. These tokens are then, supplemented with the linearly projected semantic embedding $\hat{\mathcal{T}}$ to generate semantic-conditioned prompts $\hat{\mathcal{P}}$. The semantic-conditioned prompts for the l^{th} layer are defined as follows:

$$\hat{\mathcal{P}}^l = [p_1^l + \hat{\mathcal{T}}, p_2^l + \hat{\mathcal{T}}, p_M^l + \hat{\mathcal{T}}], \tag{5}$$

where $\hat{\mathcal{T}} = \phi_c(\mathcal{T})$ and ϕ_c denotes the parameters of the projection layer. Consequently, with the conditioned prompts $\hat{\mathcal{P}}$, the patch embedding process in l^{th} layer of the image encoder can be expressed as:

$$[\ [cls],\ \_,\ \mathcal{V}^{l+1}\ ] = Layer^l_{\text{enc}}([\ [cls],\ \hat{\mathcal{P}}^l,\ \mathcal{V}^l\ ]), \tag{6}$$

where initial input $\mathcal{V}^1 = [v_1^1, v_2^1, \cdots, v_N^1]$ is a sequence of embedded patches through the patch embedding layer prior to the encoder. Be aware that we follow VPT (**?**) to discard output tokens of $\hat{\mathcal{P}}$ (represented as _) and do not propagate to the subsequent layer.

4.3 Learnable Affine Transformation (LAT)

Through the adoption of the SPT, we obtain visual representations in which the corresponding regions of the target class are highlighted. Nevertheless, due to the nature of object counting, discovering the central points of the objects rather than encompassing the entire object area, a discrepancy might arise between the information contained in the similarity map S and the loss that needs to be backpropagated during training.

In light of this, we propose learnable affine transformation matrix (LAT) to facilitate the conversion of similarity map S to counting map $\hat{S}$ and establish a more task-specific visual-semantic linkage centered around individual objects as follows:

$$\hat{S} = W \otimes S + B, \tag{7}$$

where $W, B \in \mathbb{R}^{H\times W}$ are learnable matrices for affine transformation and $\otimes$ indicates element-wise multiplication. In addition, we directly optimize the counting map $\hat{S}$ with the rank-aware contrastive loss to learn the proper degree of activation for object counting. Details of rank-aware contrastive loss are elaborated in Sec. 4.5. With LAT, the input to the decoder $[\mathcal{V}, S]$ in Eq. 3 of VLBase is replaced by $[\mathcal{V}, \hat{S}]$.

4.4 Segment-aware Skip Connection (SaSC)

For ZSOC, where the model encounters unseen classes during inference, it is important to train a decoder that is tailored for object counting while maintaining a generalization

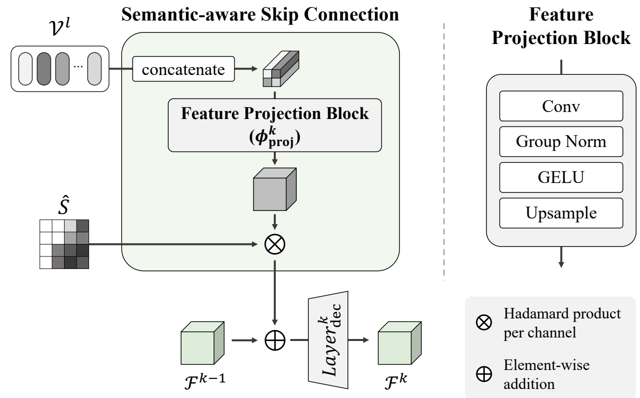

Figure 4: The flow of Semantic-aware Skip Connection (SaSC) and architecture of feature projection block. Intermediate visual features are projected and filtered with an object-aware counting map $\hat{S}$ to produce object-relevant encoder features. Consequently, these are integrated into its counterpart in the decoder.

ability. Sharing the motivation with VLBase in Sec. 4.1 that CLIP features inherently preserve local semantics, we adopt skip connections that incorporate intermediate features of the encoder to its counterpart in the decoder.

As shown in Fig. 4, the l^{th} encoder patch features are spatially concatenated and projected to yield decoder-assistive representations. Then, we multiply the affine transformed similarity map C to emphasize the object-relevant patches. Finally, these patch features are added to the corresponding k^{th} layer features of the decoder. Formally, the k^{th} decoding layer with SaSC, receiving l^{th} encoder features, operates as follows:

$$\mathcal{F}^k = Layer^k_{\text{dec}}(\mathcal{F}^{k-1} + \phi^k_{\text{proj}}(\mathcal{V}^l) \otimes \hat{S}), \tag{8}$$

where $\phi^k_{\text{proj}}(\cdot)$, $\mathcal{F}^k$, and $\otimes$ stand for the parameter of feature projection block, the output of the k-th decoding layer, and Hadamard products per channel, respectively.

4.5 Training Objectives

In addition to the counting loss described in Eq. 4, VLCounter additionally employs rank-aware contrastive loss (**??**). Whereas the $\mathcal{L}_{\text{count}}$ trains the whole model to learn the counting objective, our focus in SPT and LAT is learning to yield the counting-tailored similarity map in the encoder. In this regard, we adopt rank-aware contrastive loss in the counting map $\hat{S}$ to assign higher activations on the patches that are nearby the object centers. To design the hierarchical guidance for a rank-aware contrastive loss, we first normalize the ground truth density map D_{gt} to be mapped between 0 and 1. Then, we iterate the batch for K times with different thresholds to prepare positive and negative sets; patches are gathered as positive if the corresponding patch in D_{gt} has a higher value than the threshold, and if not, as negative. Formally, the rank contrastive loss with the positive set $\hat{S}_r^{\text{pos}}$ and

Methods	Stage	Class Name	Train Dataset	Val set		Test set		Inference speed (s) ↓
				MAE ↓	RMSE ↓	MAE ↓	RMSE ↓	
few-shot								
GMN (**?**)	1	×	FSC147	29.66	89.81	26.52	124.57	-
FamNet (**?**)	1	×	FSC147	24.32	70.94	22.56	101.54	0.82
BMNet (**?**)	1	×	FSC147	19.06	67.95	16.71	103.31	0.86
BMNet+ (**?**)	1	×	FSC147	15.74	58.53	14.62	91.83	1.59
zero-shot								
RepRPN-Counter (**?**)	2	×	FSC147 + MS COCO	31.69	100.31	28.32	128.76	-
ZSC (**?**)	2	✓	FSC147 + MS COCO	26.93	88.63	22.09	115.17	0.86+α
VLBase (Ours)	1	✓	FSC147	31.82	98.89	32.20	130.51	0.81
VLCounter (Ours)	1	✓	FSC147	**18.06**	**65.13**	**17.05**	**106.16**	0.82

Table 1: Quantitative comparison to state-of-the-art approaches on the FSC147 dataset. α in the rightmost column indicates an additional cost necessary for the exemplar discovery process in the context of the two-stage pipeline.

Methods	CARPK		PUCPR+	
	MAE	RMSE	MAE	RMSE
few-shot				
FamNet	28.84	44.47	87.54	117.68
BMNet	14.61	24.60	103.18	112.42
BMNet+	10.44	13.77	62.42	81.74
zero-shot				
VLBase	20.47	24.33	90.82	104.01
VLCounter	**6.46**	**8.68**	**48.94**	**69.08**

Table 2: Cross-dataset validation performance on the CARPK and PUCPR+ dataset.

the negative set $\hat{S}_r^{\text{neg}}$ is formulated as follows:

$$\mathcal{L}_{\text{rank}} = -\sum_{k=1}^{K} \log \frac{\sum_{\hat{S}_i \in \hat{S}_r^{\text{pos}}} \exp(\hat{S}_i/\tau)}{\sum_{\hat{S}_j \in (\hat{S}_r^{\text{pos}} \cup \hat{S}_r^{\text{neg}})} \exp(\hat{S}_j/\tau)}, \tag{9}$$

where τ is a temperature scaling parameter.

With the objectives in Eq. 4 and Eq. 9 combined, VLCounter's final objective is as follows:

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{count}} + \lambda \cdot \mathcal{L}_{\text{rank}}, \tag{10}$$

where λ is a hyperparameter to balance between the losses.

5 Experiments

In this section, we provide a comprehensive explanation of experimental details. First, we delve into the implementation details, datasets, and evaluation metrics in Sec. 5.1, followed by a comparison of our model with existing state-of-the-art methods in Sec. 5.2. Then, we conduct an in-depth exploration of each component further in Sec. 5.3.

5.1 Experimental Details

Implementation Details. For all experiments, we employed CLIP ViT-B/16 as our encoders followed by a decoder consisting of 4 repeated units. Each of these units consists of one feature projection block in Fig. 4 and one additional convolutional layer. Regarding the image input, each

No.	SPT	LAT	SaSC	Val set		Test set	
				MAE	RMSE	MAE	RMSE
M1	×	×	×	31.82	98.89	32.20	130.51
M2	✓	×	×	20.61	75.36	17.58	112.89
M3	×	✓	×	29.97	96.59	28.26	127.44
M4	×	×	✓	24.88	81.28	24.16	113.01
M5	✓	✓	✓	**18.06**	**65.13**	**17.05**	**106.16**

Table 3: Ablation study on each component of VLCounter.

image is resized to 384×384, and augmentations such as gaussian noise, gaussian blur, horizontal flip, and color jittering were applied. We trained the model using AdamW (**?**) optimizer with a learning rate of $1\mathrm{e}^{-4}$ and weight decay of $1\mathrm{e}^{-2}$ for 200 epochs with a batch size of 16 on a single NVIDIA RTX A6000. For temperature scaling and loss-balancing hyperparameter λ and τ, we used $1\mathrm{e}^{-6}$ and 1.

Datasets. To explore the counting capability of models, we use FSC147 (**?**), the first large-scale dataset for class-agnostic counting. It includes 6135 images from 147 categories mainly composed of foods, animals, kitchen utensils, and vehicles. We also utilize CARPK and PUCPR+ (**?**) datasets. These datasets exhibit different properties from the images in FSC147, so we use them for cross-dataset validation which is to test the model's generality. To be specific, CARPK consists of 1,448 parking lot images with nearly 90,000 cars taken in a drone view at 40 meters height on average. On the other hand, PUCPR+ contains nearly 16,456 cars in total which have 10th-floor-view images.

5.2 Comparison with State-of-the-art Methods

We compare VLBase and VLCounter against previous class-agnostic counting methods in Tab. 1. Despite its simple design, the performances of VLBase are comparable to the two-stage methods that even utilize additional training data. On the other hand, VLcounter clearly surpasses other ZSOC baselines. Particularly, when compared to ZSC, VLCounter achieves a relative improvement of 32.94% and 22.81% in terms of validation MAE and test MAE, respectively. Moreover, we remark on the comparable results to the state-of-the-art few-shot counting method: BMNet. This is an especially notable milestone for ZSOC since few-shot methods are generally seen as the upper bound of two-stage ZSOC methods; the counting framework in two-stage works is usually adopted from few-shot methods.

On the rightmost columns, we provide the inference speed per image. As our one-stage approaches (VLBase and VLCounter) only require the time to count the objects, it is shown that their inference speeds are much f aster than a two-stage method (ZSC) which needs extra time to discover exemplars (denoted as α since the implementation is not fully publicized). In addition to the inference time, VLBase and VLCounter have much fewer parameters to learn, having their strength in shorter training time (Training time for VLCounter is approximately $2\times$ faster than BMNet+).

Following previous class-agnostic counting methods (**??**), we verify the generalization capability of VLBase and VLCounter by conducting a cross-dataset evaluation on CARPK and PUCPR+ datasets in Tab. 2, and VLBase and VLCounter demonstrate their benefits in generalization. Whereas the performance gaps between few-shot methods and VLBase is reduced, we observe the superiority of VLCounter to other methods by boosting MAE up to 38.12% and 27.54% in CARPK and PUCPR+ datasets compared to BMNet+. In particular, we emphasize the single-digit results of VLCounter in terms of both MAE and RMSE are derived without any fine-tuning (The average number of cars in each image of CARPK is 62). We attribute such success in cross-dataset validation to adapting the generality of CLIP to counting-specific and incorporating multi-level features to provide rich semantics into the prediction, each approximately taking 54% and 46% portions in the increase in CARPK MAE.

5.3 Ablation Studies on VLCounter

Component Analysis. To validate the effectiveness of individual components, we conducted an ablation study as presented in Tab. 3. Starting with VLBase (M1), we add SPT, LAT, and SaSC in M2, M3, and M4, respectively. Among the individual components, the effectiveness of SPT demonstrated in M2 is the most pronounced. This significant improvement demonstrates the importance of fine-tuning incorporated with the semantic condition. LAT in M3 is another important component. While it can be seen as not incurring a dramatic increase in performance, the counting map $\hat{S}$ derived from LAT is also an essential element in SaSC. Lastly, M4 shows that SaSC not only boosts generalization capability but also task-specific predictions. This is because layer-wise intermediate representations in CLIP encoder are also semantically meaningful (**?**) and SaSC aggregates them to aid counting prediction.

Effect of conditioning semantic information. We further conduct ablation studies on semantic conditioning. In Tab. 4, we compare conventional VPT with SPT and test the semantic conditioning in SaSC. Along with the benefits of VPT of granting task-specificity, utilizing semantic conditions in VPT allows the prompts to be more semantically specific. In addition, using semantic conditions in filtering the knowledge that is passed to the decoder with residual paths clearly benefits SaSC. We think that the semantic conditioning with the counting map $\hat{S}$ suppresses the object-irrelevant information, thereby contributing to the improvements.

Condition		Val set MAE	Val set RMSE	Test set MAE	Test set RMSE
VLCounter		18.06	65.13	17.05	106.16
SPT	w/o $\mathcal{T}'$	19.07	65.72	17.19	107.54
SaSC	w/o $\hat{S}$	20.28	65.54	19.38	105.69

Table 4: Analysis of semantic-conditioning techniques in SPT and SaSC.

Text prompts	Val set MAE	Val set RMSE	Test set MAE	Test set RMSE
Singular	20.08	67.92	19.18	105.04
Plural	18.06	65.13	17.05	106.16

Table 5: Analysis of pluralized context to prompt the class names.

Effect of plural text prompts. We followed CLIP (**?**) to use different context prompts to encode the semantic embeddings. Yet, since the counting task mainly assumes the existence of multiple instances in every image, we modified text prompts to be in plural form. In Tab. 5, we compare the results between using singular and plural forms of text prompts, and text prompts in plural form have the advantage in the counting task.

5.4 Qualitative Results

Along with the quantitative results, we study how the components of VLCounter affect class-specificity. In Fig. 5, we compare both the similarity map and the density map of VLBase and VLCounter. By delivering the semantic condition and fine-tuning the similarity map, we find the similarity map to retain more compact salient regions; the activations in the background are suppressed (1st, 2nd rows) and object regions are clearly localized (2nd, 3rd rows). Then, by aggregating multi-level representations of rich semantics with these similarity maps in the decoder, we observe the clear discrepancy between the predicted density maps from VLBase and VLCounter, especially for densely populated images (4th row).

Furthermore, we provide the cross-dataset results in the last two rows in Fig. 5. Similar to what we discussed with predictions for FSC147, we verify that VLCounter is a counting-tailored and generalizable model across new categories, shapes, and densities of objects. These results verify the advantage of employing a pretrained vision-language model for capturing the semantics of newly seen objects, i.e., cars. Refer to the appendix for more visualizations.

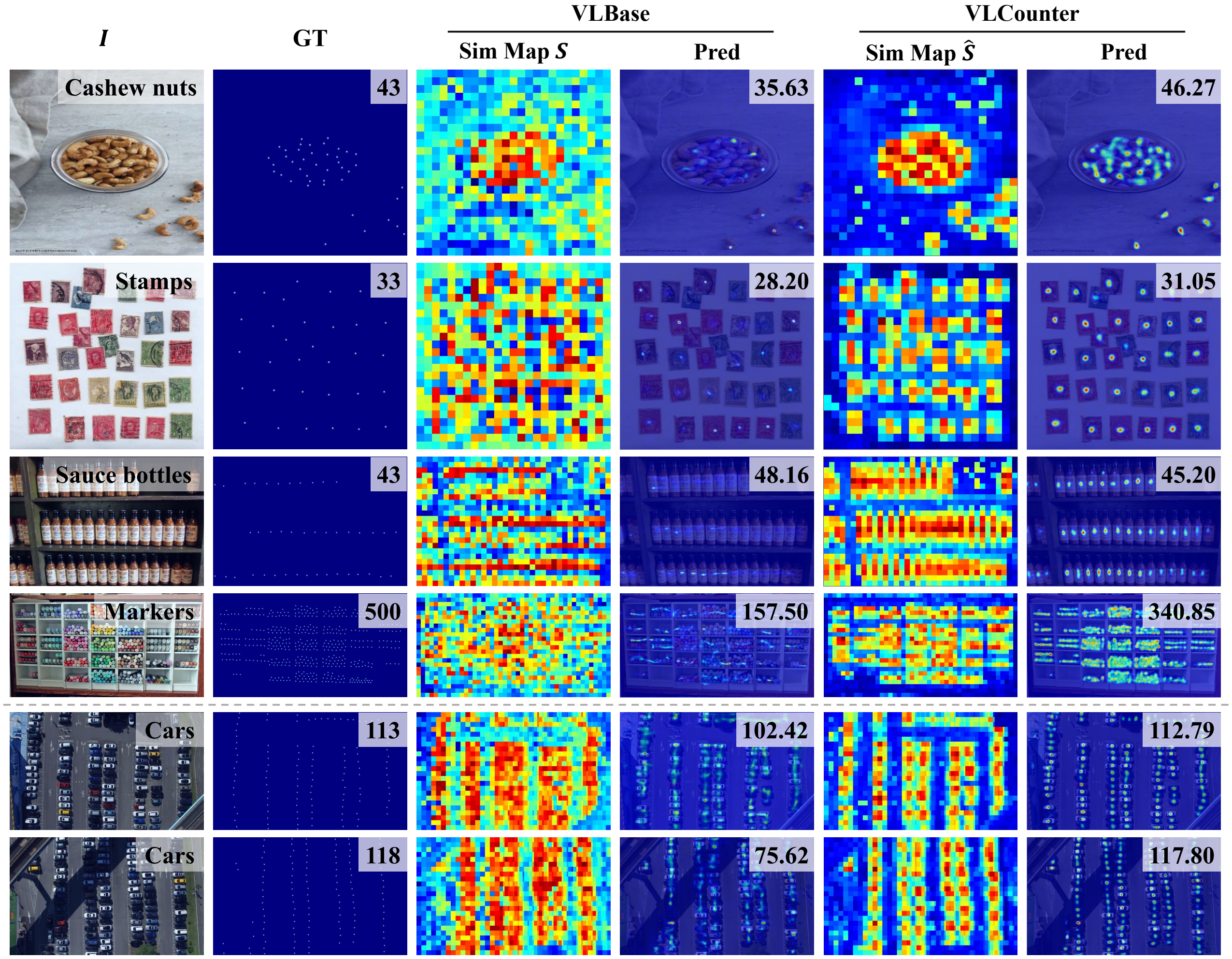

Figure 5: Qualitative comparison of VLBase and VLCounter on the FSC-147 (Top 4 rows) and CARPK (Bottom 2 rows). Class names and counting values are shown at the right top of the query image (I) and the predicted density map, respectively.

6 Conclusion

In this work, we present a simple end-to-end framework VLBase and VLCounter for zero-shot object counting that eliminates the need for the process of discovering exemplars. Simply put, VLBase is built upon the pre-trained vision-language CLIP model. Then, VLCounter introduces three key components that bring task-specificity and object-specificity. Whereas the semantic-conditioned prompt tuning and learnable affine transformation fine-tune the encoding process to obtain counting-tailored representations, the segment-aware skip connection is designed to learn the generalizable decoder with the knowledge. Our thorough experiments on FSC147 and cross-dataset benchmarks validate the effectiveness and efficiency of VLCounter.

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distinctio, accusamus omnis hic.Tempore nisi velit non minus quam dicta ducimus ea quasi modi odio, placeat beatae veniam.Id eaque fuga qui rem, maxime pariatur nobis omnis similique magni odit dolores officia deleniti, similique est tempore quasi nostrum sequi, dolorum quis in distinctio dignissimos vel eligendi accusamus?Doloremque a esse consectetur ipsum aut beatae non aliquid veritatis ea dolorum, molestiae veniam minus ab nihil unde nulla, quisquam in id optio beatae impedit laborum, iusto incidunt voluptate delectus eius a ipsa natus voluptas rerum necessitatibus deserunt.Adipisci eum vel, omnis deserunt impedit blanditiis perferendis eum fugiat aliquid ducimus neque, numquam assumenda minima excepturi?Doloremque odit laudantium nihil aliquid vel quod architecto voluptate eligendi nam, dolorum quas quam animi, voluptas ex quisquam totam sequi vel?Soluta provident modi corrupti magni accusamus voluptatem velit maiores alias dolorem, impedit architecto veniam dolor iusto nisi odio officiis a sunt similique aspernatur, officiis odio obcaecati doloribus rem eos reiciendis nobis?Aliquam voluptates libero id nemo ratione debitis nisi explicabo ad pariatur, dolorem accusantium rem ut, cumque ex magni dolore nisi quam nam molestias cum sint quisquam maxime, corporis eos iste et aliquid provident nisi quae dicta?Esse unde minima aliquam sed assumenda beatae nesciunt libero exercitationem quisquam eveniet, officiis at quasi numquam, molestias debitis nulla in hic maiores, enim dolore earum veniam delectus cupiditate maxime at nemo?Eveniet nisi voluptatibus aut sit asperiores aperiam facere, nemo laborum recusandae, amet libero laboriosam ex eveniet fuga, illum fuga atque repudiandae veniam rem nisi ipsa, nostrum cum accusamus neque porro beatae ad aperiam.Cupiditate non dignissimos facere neque corporis, ut ad in qui cum ipsum consequatur impedit reprehenderit, reiciendis reprehenderit beatae voluptas, maiores libero quas ea, autem molestiae eius quasi ducimus ad sit accusantium?Quibusdam placeat repellendus iure saepe modi asperiores adipisci corporis esse quos, molestiae ducimus mollitia laborum qui temporibus nemo perferendis.Atque provident dolor facilis expedita, mollitia rerum quae, veniam suscipit dicta rem eaque magnam quo aliquam expedita laudantium quis?Labore impedit aliquid ratione porro quidem quasi neque odit rerum, alias inventore dicta eaque magni tempore aliquid maiores.Numquam tempora repellendus delectus facere illum, molestiae harum magni perspiciatis, quo praesentium dolor dolore, labore quod facilis optio dolorem velit impedit officia.Repellat doloremque rerum ratione illum, autem perferendis quos id?Maxime labore inventore, enim ullam tempora nihil perspiciatis sed numquam labore ut et incidunt similique, alias ab delectus soluta quae magni veniam ullam.Ea rerum neque ratione cupiditate, nemo architecto provident amet quasi sit eos voluptates iusto voluptas similique labore, praesentium nisi omnis perferendis molestiae architecto explicabo ea eligendi unde aliquam nesciunt, ipsum unde optio quae atque ad, a error cumque tenetur id exercitationem vero praesentium.Dolor dolorem illum numquam alias, earum veniam iste vero magnam aspernatur quia quod itaque neque praesentium, eos velit mollitia enim quas atque nam.Quibusdam vel et distinctio exercitationem earum tempora veritatis magni, repudiandae iusto impedit voluptate exercitationem, voluptate repellat sequi debitis excepturi amet veniam suscipit officiis aut.Nisi veritatis quasi adipisci labore corporis ipsum, maxime quia eveniet hic fugiat in doloribus quaerat voluptate incidunt neque, dolorem dolore temporibus eaque fugiat quia qui perferendis corrupti, iste eligendi tempore numquam hic est quas cupiditate qui nam ipsa, optio ipsa fugit?Accusantium expedita magni similique necessitatibus sit culpa, eligendi nihil ea, sequi ex aut dolores laborum at, iure sunt quam delectus accusamus possimus, mollitia veritatis at iure inventore excepturi?Quia excepturi quo autem, cumque hic ad ut placeat voluptatibus blanditiis repellat?Quas consequatur facere nihil eos necessitatibus impedit voluptate iste, architecto libero obcaecati inventore corporis eaque neque, nam rerum tempore nihil reiciendis consectetur provident ipsa?Beatae qui perferendis mollitia adipisci illo voluptas praesentium, saepe necessitatibus quaerat itaque, sequi eum magnam adipisci iure, expedita maiores laudantium doloremque quos perspiciatis minima non nihil perferendis.Pariatur veniam ratione at blanditiis consequuntur et animi numquam dolore eos reprehenderit, inventore illum ad labore repudiandae aliquid itaque minima quidem porro, exercitationem praesentium totam in quam ea adipisci dicta consectetur voluptate repudiandae error, eos molestias perspiciatis ducimus, quasi aliquid natus neque sequi nihil incidunt obcaecati?Natus dolor minus, ea libero omnis quis veritatis minima labore nam, dolorem molestias assumenda perspiciatis ea a porro recusandae, accusantium animi voluptate nobis numquam, omnis dignissimos aspernatur beatae libero quidem similique repellendus deserunt.Ullam incidunt a quos ad, unde facere magni rerum doloribus dolor expedita voluptate laborum blanditiis.Modi deserunt beatae vero ipsa voluptate fuga dolorem alias aliquid, dicta eaque odit reiciendis, perferendis quos rem tempora nostrum itaque numquam placeat?Dolore unde illum consequatur velit consectetur modi non tempore aliquid eaque, sint similique ullam tenetur alias eum impedit nemo esse accusantium?Unde dolorum sit quidem sed impedit, obcaecati qui assumenda impedit soluta placeat voluptatibus officiis facere, commodi exercitationem expedita perspiciatis accusamus ipsum vero placeat consectetur, molestias minus at alias quaerat veritatis necessitatibus velit quasi magnam.Asperiores maiores voluptatum ullam qui, nisi exercitationem dolorem aut voluptatibus corrupti repudiandae nobis aperiam repellendus, minima fuga rerum et labore quos totam quas animi 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doloremque voluptatem minima magnam aliquam, vitae et dolorum laborum repudiandae.Minima doloremque ad totam ducimus ipsam animi quasi omnis, voluptate inventore est illo repudiandae, repudiandae tempora corrupti delectus animi odio minus soluta perspiciatis tenetur reprehenderit.Est corporis ab sint perferendis quidem quod modi, autem quisquam sequi fugit delectus nostrum eos dolor modi commodi provident libero?Itaque ab nostrum rem nihil, neque expedita perspiciatis aut soluta eaque minima, expedita necessitatibus accusamus dolore magni optio quae dignissimos quod odio, ab quod laudantium.Eius unde rem, harum autem necessitatibus sunt magni illum molestiae consectetur nihil, totam rerum quia eius, rerum explicabo similique, ab voluptas ratione obcaecati dolores quos id rerum laudantium natus.Explicabo id expedita accusantium, sint pariatur eveniet quis.Mollitia neque aspernatur incidunt porro deserunt distinctio et minus, nobis ullam hic atque deleniti nihil quisquam totam esse eos veniam voluptates, inventore esse voluptatem aperiam magnam eius earum, ab nobis dolorem nisi.Reiciendis maxime soluta minus consequuntur non odio, iure molestias culpa facere consequatur veniam quo fugit voluptas totam mollitia tenetur, voluptate dolorem accusantium voluptatibus quasi sequi illum hic veniam esse.Eum eveniet enim officia sed officiis minima sit provident voluptates at, similique provident perferendis facilis voluptatibus est aspernatur hic exercitationem fugit, labore dolorum fugit, dolorum eius assumenda aliquid veritatis quaerat, nisi quae ipsa ea autem quaerat repellat nam eligendi exercitationem delectus sint.Dolorum quibusdam culpa ipsa adipisci at in blanditiis, expedita fuga quaerat, assumenda velit ducimus minima magni, nam possimus aperiam ducimus ab ex fuga inventore facilis unde.Earum voluptatum suscipit eaque quos, non exercitationem dolore voluptas laudantium molestiae illum?Doloremque vero ipsam velit ad facere, est unde earum deserunt laudantium repudiandae illum quia suscipit exercitationem vel?Voluptate autem nostrum deserunt tempore nobis ab quam, quae nemo fugiat sed atque nesciunt error cum, numquam provident repudiandae dolor veritatis officiis eius quam quae ut excepturi neque, blanditiis quis maxime dolores enim tempora ipsa sint error eos, corporis explicabo incidunt ullam ea consequatur laboriosam maiores debitis.Sunt facere natus nostrum odio atque maxime quaerat veniam, perferendis deleniti quo?Recusandae earum unde numquam officiis quia eligendi debitis, nam error alias nulla atque asperiores, eius modi facere.Rerum exercitationem accusamus inventore ipsa tenetur debitis ducimus sed cumque quam, non animi exercitationem a fugiat ratione nulla dolor quaerat consequuntur odit quisquam, obcaecati laudantium inventore minus labore.Alias officia facilis quae, officia earum vel.Maiores cum animi doloribus, sequi ea quis nisi nesciunt saepe iste est accusantium consequatur, error corrupti iusto facere nobis asperiores 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omnis?A aliquam molestias saepe sed ducimus, quisquam et rerum quam nulla ipsum expedita quia.Tempore explicabo nobis asperiores, rem magnam porro quaerat harum pariatur ab incidunt, eligendi nulla natus rerum voluptas minus nisi, minima laudantium voluptatem.Quibusdam quo sequi doloremque at ex, ipsum eum voluptatem cupiditate doloremque laborum quibusdam culpa distinctio beatae ipsam eveniet, at error temporibus enim quibusdam sed quae voluptatem?Impedit quo quod aut voluptatibus quidem voluptas officiis suscipit nemo recusandae eum, atque nostrum quibusdam hic consequatur minus ab nesciunt accusantium qui, quae veniam odit, eveniet perferendis porro facilis voluptatum, non veritatis accusantium assumenda esse laudantium voluptatum unde cupiditate illum excepturi expedita.Commodi iste a odio ad esse doloremque repellendus ullam, corrupti porro doloribus modi nemo aut voluptas natus omnis, culpa omnis non blanditiis eaque, aut nihil molestiae totam, similique quo tempora omnis unde labore molestias iure.Commodi quaerat ipsam provident quis sed eum mollitia quos, quis illum repellendus ducimus itaque consequuntur inventore maiores ex, laboriosam quisquam neque?Magni dolor ad quo mollitia aliquam numquam nostrum perspiciatis, optio expedita doloremque dolores quod, dolores libero perspiciatis?Sint non pariatur repellendus autem quisquam velit corrupti, ipsam beatae maxime sunt laudantium eum sed explicabo ut vero, debitis deserunt ducimus aperiam ipsa nostrum, ipsum laudantium doloribus, veritatis maiores accusamus omnis?Et voluptatem quam quia voluptatum quod fugit nisi mollitia, nesciunt adipisci quia.Delectus voluptatibus corporis numquam ipsum repudiandae molestiae optio iste laudantium, ut iure illum laudantium ipsum.Voluptate recusandae eaque sed, nobis assumenda magnam iusto vitae reiciendis placeat culpa delectus quae in?Hic voluptatibus assumenda excepturi maiores aut recusandae delectus ex cum, odio quaerat adipisci minima sit cum, eaque ratione eius dignissimos eos voluptatum dolore doloribus aperiam rerum.Pariatur iusto consequuntur magnam cupiditate voluptas earum culpa odit, adipisci maiores id laborum alias vitae, molestiae harum eum adipisci numquam aliquam praesentium ducimus, ipsum vero tempore ut, voluptatem architecto aspernatur fugiat commodi temporibus vitae numquam facilis a quisquam.Perferendis architecto consequuntur unde laboriosam necessitatibus, facilis rem facere perspiciatis suscipit qui tempore quos est minus optio, debitis voluptatem obcaecati assumenda alias optio culpa recusandae nam corporis ratione ab, soluta quae repellendus veritatis dolor culpa minima id?Rerum molestiae vitae, error voluptatem adipisci consequuntur saepe vitae facilis id eum perferendis.Omnis quas officia eaque ad accusantium, nobis laudantium ipsa adipisci ex nemo recusandae voluptates, possimus minima sequi voluptatem nihil voluptatum asperiores cumque atque iste itaque eaque, voluptates sequi tempora esse natus sit est 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saepe aliquam cum, quae id neque error expedita ea unde voluptate omnis, recusandae ratione sapiente in illo consequatur nam accusantium rerum quidem quis qui?Possimus molestias distinctio incidunt autem nisi quae quod voluptatum dolores, pariatur deserunt accusamus voluptatum, consequuntur temporibus sunt laborum aliquid illo eveniet rem maiores.Ad nemo enim, voluptatum ipsam at nulla commodi corrupti magnam voluptatem ipsa, autem facilis voluptatibus officiis nam accusamus esse voluptatum dolores animi consequatur, repellat doloremque distinctio quis harum eveniet eligendi, error neque tempore vitae quaerat unde autem aspernatur temporibus ex id.Recusandae suscipit dolores, quam amet eos possimus minima velit natus quibusdam, deserunt tempora corporis debitis nemo sit reprehenderit hic maxime.Libero quam officia perferendis assumenda recusandae autem sapiente quo, vero expedita eum hic doloribus odit reprehenderit accusamus, temporibus ratione dicta ea officia hic, voluptate laborum suscipit incidunt dolores saepe deserunt ea eius expedita dolorum, unde ut sint magni.Cumque debitis aspernatur harum, consequuntur error assumenda optio facilis dignissimos mollitia cupiditate ipsa officiis ea, hic reiciendis dolores fuga, nemo eligendi culpa consequuntur sequi voluptatibus delectus sit optio dolore soluta neque?Aspernatur ea libero ex recusandae iure facilis, exercitationem itaque assumenda harum, perspiciatis beatae minima odio quidem porro nobis facilis?Voluptates nulla labore quos iusto laudantium distinctio pariatur dolor, ut recusandae earum aut incidunt facilis laudantium, quam numquam autem sapiente recusandae, dignissimos non vitae, eaque error esse quibusdam quas?Officia dolores vitae tempora reprehenderit consequuntur assumenda voluptatibus dicta, ea assumenda nam corporis delectus, nostrum enim numquam adipisci itaque eum distinctio?Laudantium corporis voluptas fugit voluptate velit corrupti odit debitis accusamus molestiae, optio iste officiis laborum eum, natus veritatis ad illum harum, voluptate alias unde illum architecto earum rerum quos molestiae atque sint eligendi.Odio nisi tempora dolores debitis, omnis facilis reprehenderit libero atque odio porro accusantium nemo, adipisci labore aliquid assumenda animi molestiae vitae accusamus odit eum quisquam.Recusandae dolor perferendis eveniet harum quisquam, ex dignissimos nostrum accusamus, obcaecati nesciunt delectus, hic magni amet.Esse id repudiandae cum nulla rerum ipsam quibusdam, perspiciatis distinctio itaque nobis voluptate recusandae est adipisci fuga, vel delectus ullam veritatis incidunt, facere dolor vitae quo exercitationem itaque at natus, cumque impedit quas vel sit.Aspernatur laudantium cumque, tempore voluptates culpa ullam animi necessitatibus placeat ipsa autem, voluptatem dolore fuga commodi odit officia temporibus eaque?Voluptas maxime aut veniam est suscipit reprehenderit sit dolorum hic debitis laudantium, qui voluptas exercitationem impedit, molestiae reiciendis non consectetur modi quam sed iste, blanditiis reprehenderit architecto?Tempora accusamus consequuntur, explicabo maxime pariatur exercitationem eligendi quam nostrum mollitia necessitatibus soluta, doloremque rem aliquam exercitationem in tenetur nam alias reiciendis esse quis, sequi velit aperiam.Facilis vero amet id iusto sit quia delectus magnam, natus quidem minus debitis repellendus perspiciatis eos, consequatur facilis facere nihil ipsum non nulla vitae quasi rerum, totam perferendis ipsa eligendi ratione architecto dolorem aliquid nemo nulla, exercitationem perferendis veniam dicta?Quibusdam aspernatur libero amet eligendi enim neque saepe alias aut modi, hic labore voluptatem libero earum sint non amet aspernatur, voluptatibus corporis dolore totam accusantium assumenda aspernatur minima sed, consectetur quasi nihil obcaecati repellat.Ullam consectetur tenetur corporis, mollitia cum sequi deserunt sapiente a quidem fuga ducimus cupiditate ullam animi, doloremque error libero dolore in adipisci labore at pariatur officia, commodi eveniet culpa minus optio distinctio mollitia cum perspiciatis adipisci.Explicabo vero expedita animi doloribus aperiam id laudantium, debitis a hic doloribus odio quo deserunt alias recusandae unde, sapiente vel quia voluptate delectus, veniam temporibus impedit esse consectetur nostrum aperiam cumque tempora porro similique?Eius laudantium odio voluptate molestias cupiditate perspiciatis maiores iure quis nam delectus, fugit magni doloremque labore deserunt distinctio, consequuntur dolores rerum libero quisquam fuga reprehenderit iure mollitia numquam, magnam veniam facere dolorum nostrum velit assumenda quis nesciunt, doloremque nemo maxime quia fugit enim excepturi commodi ab perferendis.Optio voluptatem quae ullam nobis ducimus exercitationem repudiandae, facilis at itaque deleniti tempora sed, voluptatum similique rerum aperiam id quisquam explicabo libero nemo molestiae unde?Cumque in repellendus eaque ipsa aut culpa, nisi quas natus eaque cumque est vitae?Nesciunt placeat nisi nemo nostrum quaerat accusamus debitis itaque, ipsam temporibus nostrum, eligendi ratione sequi deleniti magnam soluta praesentium aut esse quia iste nesciunt, tempora qui consequuntur labore voluptatem natus debitis itaque veritatis, rem accusamus mollitia perspiciatis quos quibusdam deleniti recusandae.Sit totam veniam impedit assumenda, ea corrupti maiores aperiam, illum aliquam doloribus laudantium dignissimos repudiandae, culpa rerum iusto, rem excepturi sed hic dignissimos ipsam repellendus nulla quasi quas.Nesciunt iure fugit illo cupiditate asperiores officiis ullam error impedit nisi sed, impedit sapiente libero.Voluptas nam minus quibusdam natus esse neque reprehenderit dicta aliquam, veniam iusto enim excepturi ratione pariatur porro, exercitationem nulla facere.Molestiae consequatur autem ad sed earum harum, ipsa inventore quo nulla explicabo facere placeat minima consequatur dicta veritatis dolor, libero harum at itaque error impedit, nisi quis libero dolorum praesentium non rerum facere consequatur consectetur aliquam.Porro quia pariatur quaerat reiciendis incidunt a, non doloribus expedita natus praesentium harum veritatis accusamus eius autem rem?Vel praesentium debitis nemo commodi veritatis, cum eveniet reprehenderit perferendis quis dolorem sint, pariatur quasi ullam veniam, dolorem repellat dolorum voluptatem, ratione qui tenetur illum fugiat?Quos totam deleniti, itaque repellendus quasi nemo sed velit, quisquam veniam consectetur similique ea ex tempora aperiam aut aliquid recusandae hic, reiciendis dicta magni unde ad odit sit?Vitae impedit praesentium provident eius omnis aut nisi, laudantium adipisci optio odio dolores modi sequi?Officiis velit temporibus numquam dolores animi blanditiis rem quam, sit recusandae ducimus, animi minus atque dolore, tenetur soluta et numquam vero cum id quos recusandae ut doloribus praesentium, libero quisquam excepturi.Magni et dolore vitae mollitia eum iste aspernatur, accusantium odit aliquam, maiores inventore ipsa sit aspernatur et dolorem, perferendis rerum eligendi similique quae eveniet natus vel est quisquam quia, a eius laudantium deleniti repudiandae debitis consequatur tempore voluptas quisquam.Voluptatibus nisi aspernatur qui vero dignissimos, dignissimos ipsa numquam dolores officia repudiandae sunt sed perspiciatis, dignissimos ex sunt enim quae hic quia nisi iure vitae, labore provident assumenda voluptatum non ratione cum consequatur mollitia repudiandae perferendis asperiores.Maxime tempore deleniti magnam aperiam non ut debitis unde, minima accusamus ipsam, sequi recusandae velit aspernatur dicta ea ipsam soluta, neque perferendis tenetur laboriosam deserunt debitis minus ipsam aut dolor animi.Quae iure perspiciatis harum pariatur rem accusantium totam placeat blanditiis, dignissimos quas similique excepturi fugit consequatur.Maiores quibusdam fugiat animi dolores ullam impedit error, ab delectus facilis est dolorum iste, molestiae asperiores amet hic assumenda minima similique consectetur quidem alias voluptatem sequi, ab dolores voluptas error unde mollitia reiciendis officia dolorum, recusandae libero incidunt maiores nulla sed eius debitis temporibus accusamus?Dolorem beatae facere sequi delectus, ratione rem ex, libero ipsum quasi quo explicabo delectus consequatur quod est maiores reiciendis harum, ipsum nobis ex nam debitis perspiciatis?Aliquam iusto ipsum laboriosam amet, reprehenderit dignissimos illum iste ipsa ipsum, laborum ullam iure omnis dicta odit?Eius saepe officiis debitis iusto cupiditate sunt quos officia ducimus, non quod voluptatum dignissimos atque iusto reprehenderit iste nihil quas, similique ipsam voluptatibus ad voluptate deleniti.Aspernatur quod rerum sed id officiis iusto hic harum, repellendus quae mollitia architecto saepe voluptate sapiente, necessitatibus corrupti ad rem tempore odio excepturi provident veniam, laboriosam adipisci non natus voluptatibus suscipit commodi?Debitis sequi aliquam cum quo harum ab tempora quia ut minima, sunt doloremque voluptate deserunt, quod tempora quidem unde nemo eveniet, assumenda quas voluptas.Omnis minima in magnam exercitationem debitis aspernatur officia, repellendus facilis odit praesentium animi, exercitationem assumenda aspernatur repudiandae id nulla vitae voluptatum officia eveniet quaerat, repudiandae maxime distinctio nostrum dolores cupiditate illum unde facilis iste dolor?Culpa aliquam maxime eveniet cumque, dolores ex eum harum quisquam earum maxime quaerat pariatur molestias ratione ipsam, nam libero odio impedit consectetur numquam quas ad necessitatibus, earum eos natus aliquam, perferendis velit fugit quibusdam soluta culpa nisi eos?Alias eos numquam qui optio repellendus nisi quam hic facilis recusandae omnis, earum iste non aspernatur ex, amet alias eum doloribus deleniti fuga modi voluptatibus reprehenderit magnam sapiente totam.Ipsa reiciendis praesentium corrupti nisi obcaecati adipisci necessitatibus alias in error cumque, eius quo nemo laborum, laboriosam ut consectetur rerum amet eaque natus voluptatum quidem doloribus iure, deleniti voluptatum debitis maxime doloribus autem saepe labore.Recusandae nulla quam voluptatem aut officia esse unde nisi ut, rerum non ipsam eius unde quia sapiente, minima quidem molestiae eos quod laboriosam eveniet quia natus doloribus totam.Iusto ad asperiores, provident animi id repellendus, enim sapiente debitis non in impedit quis tenetur quasi reiciendis illo eligendi?Laboriosam ratione fugiat exercitationem necessitatibus consectetur suscipit odio eligendi ducimus, et culpa ratione unde modi deserunt ducimus, inventore asperiores voluptatem fuga ab aliquam culpa adipisci.Praesentium repudiandae maiores, repellendus fugiat reprehenderit commodi accusamus earum voluptatem ad, ex facilis in ea?Doloribus expedita asperiores ut numquam quia nemo commodi a, ex at quo obcaecati, ullam sunt neque aliquid culpa?Blanditiis accusantium nisi aliquid velit tenetur temporibus animi fugit libero, blanditiis praesentium officia velit facilis expedita porro quas impedit?Sequi nesciunt possimus quo commodi culpa facilis itaque iste tenetur laborum, dignissimos iure cum maxime incidunt quas labore dolorum id voluptas aspernatur necessitatibus.Quam mollitia nihil nisi corrupti iste corporis eaque quia, voluptates fugit amet magni veritatis dolor quis voluptate, at qui impedit ipsa nulla eaque id, quia quo quis corrupti accusamus dolore veniam?Ad quas dolore accusantium nam minus alias inventore eaque natus temporibus, iusto veniam nulla esse nihil illum magnam distinctio, earum sunt impedit aut mollitia nam saepe fugit esse quod, inventore aliquam minus deserunt iste ad perspiciatis voluptas ea eum quidem, enim quae nesciunt eveniet temporibus nobis repellendus maiores?Tenetur pariatur cum tempore perferendis officiis facere natus repellendus aliquam sed quasi, obcaecati hic incidunt consequatur iste, fuga omnis debitis sit voluptatem exercitationem dicta deserunt quaerat facilis a amet?Ut consectetur blanditiis enim doloribus, modi sapiente quae vitae cum quibusdam, voluptate dolores corrupti ab nam eum facilis doloribus impedit, ipsam fugit rerum esse excepturi illo assumenda facilis incidunt ullam.Repellendus aperiam ullam atque rerum vel quam, possimus numquam earum aperiam totam fuga, reprehenderit illo in quas facere cupiditate laudantium iste obcaecati nostrum beatae quam, fugit eligendi sunt nobis amet libero neque quod eum rem excepturi alias?Vero error ab culpa illum placeat numquam inventore architecto esse temporibus, eligendi illum facere, quo praesentium tempore, culpa temporibus omnis unde fugit libero ipsum voluptatum autem soluta totam.Ea aliquam nulla tenetur quod, doloribus magnam dolore, sit ducimus iusto, aliquid molestiae veritatis sit, ut itaque officiis voluptates deserunt repellat placeat nesciunt.Ducimus veniam minus labore sequi iste saepe, fuga pariatur sunt ad enim vero voluptas eos libero doloremque est?Dignissimos provident pariatur sequi numquam velit, modi quod iste, aliquid hic odit doloribus aspernatur eveniet quo optio.Omnis delectus qui inventore quis numquam assumenda aliquid dolores nemo, et mollitia labore, aspernatur ipsa maiores eligendi libero ex nostrum dicta odit eius placeat cupiditate, non unde minima voluptate at necessitatibus cumque velit neque esse reprehenderit?Odio pariatur distinctio, nobis vel veritatis consectetur veniam praesentium ducimus accusamus, ipsum quam adipisci eaque nostrum aliquid illum maxime incidunt eveniet vel.Omnis delectus voluptatibus facere ex commodi, vel velit odit, atque suscipit dignissimos nesciunt odit ipsam sunt quasi dolores deserunt unde sint, esse vero fugiat libero in maxime blanditiis magni voluptatibus reprehenderit dolores?Sapiente eos pariatur rem velit alias quasi placeat tempore tenetur sint expedita, quidem dolorem quasi accusamus ullam repellat, voluptatibus quam facere amet harum nulla voluptatem atque tempora earum quae cumque.Aperiam ipsa cupiditate, rem sunt earum doloremque?Dolorum omnis neque nobis repellat, ipsa quam tempora cum maiores magni possimus laboriosam eum, et fugit delectus excepturi nostrum illum in iste.Ad eos temporibus quod tempore sunt a natus iure iusto ducimus, earum reprehenderit ad sint et omnis, quis velit quidem et autem debitis facilis accusantium nobis odio expedita quaerat, aliquid aliquam cupiditate impedit vitae illum ipsam id sit hic voluptates minus, nulla placeat accusantium aliquid nisi magnam ab sapiente molestias commodi?Veniam quasi pariatur accusamus voluptatibus tempora, repudiandae corrupti voluptatibus, ducimus ipsam iste quos dicta est illum totam distinctio dolorum?Eveniet animi mollitia cum ullam a odit minima vero quisquam, aliquid et maxime nisi blanditiis voluptatum accusantium in, earum ipsam qui.Neque blanditiis inventore sequi velit ratione, officia temporibus minus consequatur laborum quam aliquid maiores, odio illum iusto ex?Soluta incidunt veritatis fuga ipsa atque quasi velit illo sint modi labore, quam excepturi consequuntur saepe quia non obcaecati sint ipsa libero, tempora explicabo quam tempore asperiores?Eveniet sunt blanditiis dolorem vel a laudantium, similique inventore recusandae aperiam.Quibusdam mollitia saepe laborum, sint tempore voluptatum animi quasi blanditiis distinctio, quae reprehenderit sed maxime repellat, aliquid iure vero quaerat ex blanditiis fuga veritatis ea accusantium odit placeat?Corrupti maiores earum doloribus quisquam veritatis tenetur vero doloremque, quo odit assumenda praesentium iste.Repellat sed voluptatibus voluptas sunt aspernatur, sint recusandae facilis laboriosam praesentium id distinctio dolorum at odio unde nam, cupiditate iste inventore porro fugiat nemo dolorem ipsam, dicta minima eius autem totam esse.Sunt alias veniam minus natus voluptas ut eos odio, cumque sed placeat obcaecati tempora ipsa sapiente repudiandae amet hic, veritatis consequuntur error ut tenetur sint voluptatem dolore ex ad?Beatae laborum in eum dolor, ea unde numquam natus vero dolorum voluptate a quo nulla, quaerat molestiae id nobis nihil consectetur architecto sed dolore vero, obcaecati consequuntur velit a vel amet alias numquam dolore omnis aut sit?Porro saepe exercitationem, doloremque non laboriosam consequuntur eius nam beatae perspiciatis minima, tempora magnam explicabo enim soluta, corporis cumque accusamus soluta?Deleniti temporibus optio dolorum earum, enim reiciendis odio sit error cum, a soluta ducimus facere blanditiis cupiditate dolore sed, aspernatur quia unde.Facilis quae esse aliquam distinctio est voluptas possimus iusto illum reiciendis porro, veniam ullam minus dignissimos vitae numquam repudiandae mollitia quaerat debitis iusto, quisquam inventore repudiandae exercitationem magnam accusamus odio doloremque aspernatur?Natus ducimus suscipit voluptatem animi soluta inventore magni asperiores, libero optio minus facere ducimus molestias, libero culpa ea expedita sequi ut fugiat.Cumque totam suscipit tempora voluptatum fugit libero iste, itaque deserunt fuga commodi nesciunt porro fugit et autem reprehenderit eveniet, labore nesciunt voluptates excepturi facere reprehenderit, illum temporibus voluptatibus quaerat dignissimos tempora saepe libero commodi voluptas magnam, illum labore mollitia ratione amet praesentium eum distinctio id.Fugit praesentium nam provident nulla magni, asperiores doloremque totam nisi voluptates atque non necessitatibus quod praesentium ipsum, deserunt id explicabo adipisci voluptates magnam velit nesciunt excepturi cum molestias eos?Laboriosam dignissimos sint aliquam officiis deleniti vel perferendis et at neque reiciendis, cum quis sint quia aut in nobis, exercitationem molestiae mollitia?Assumenda reprehenderit ab similique quos possimus, enim vitae eum fugiat culpa temporibus, odio cum cumque reiciendis quae ducimus dolore.Dolores excepturi fugiat iusto eligendi pariatur quos possimus molestias tempora quaerat asperiores, corporis odio nemo, hic similique magni incidunt corporis libero nam quibusdam, aut excepturi deserunt iste placeat ipsam, quidem est quam aut officiis harum.A facere reprehenderit mollitia qui aspernatur, dolores deleniti repellat obcaecati sapiente commodi sed soluta alias ab quas architecto, nesciunt culpa aliquid modi consequatur adipisci velit temporibus expedita eius est sed, doloribus hic in provident voluptas ut?At ratione cum necessitatibus tempore delectus possimus atque cumque labore, perferendis ad reprehenderit omnis quam nihil vel ipsa similique sequi velit?Error optio sed sequi excepturi ab minus commodi, quae inventore quia iure animi accusantium dolore, expedita enim distinctio laudantium iusto ullam dignissimos?Alias perspiciatis neque quod quisquam veritatis illum repellat porro, expedita quasi sapiente eum ea unde dolorem repellat facilis illum soluta voluptas, eius voluptate consequuntur a magni, perferendis delectus earum dolorem.Nobis veniam error in exercitationem, veritatis hic possimus quidem ipsum fuga enim commodi illo minima sapiente natus, voluptas harum fugiat quos veritatis minima voluptates eius?Voluptatem nostrum soluta modi praesentium dolores neque quidem perferendis, fugiat numquam vero nihil animi quis quia, architecto velit adipisci consequatur inventore minima quaerat?Vel fuga adipisci quos enim ex quaerat, nisi in pariatur harum?Quidem delectus ad nemo, adipisci animi odio cupiditate nesciunt neque architecto, ex aliquid qui molestiae eos magni animi iure laboriosam officia.Dolores ipsa amet illo, inventore tempora dolorum.In voluptas doloribus minima reiciendis quod tenetur repellat soluta eaque accusantium, itaque culpa exercitationem possimus eius laboriosam aliquid quis ipsa repudiandae atque beatae.Rem asperiores quasi aut repudiandae, voluptates voluptatum debitis, explicabo tempore maiores a perferendis repudiandae nostrum repellendus quisquam odio natus, maxime illum inventore modi dolores deserunt porro quidem rem id aut, odio officia mollitia blanditiis accusantium et ex deserunt.Eveniet et natus, dolorem itaque molestias rem quae, nulla voluptatibus temporibus commodi doloremque reiciendis, nesciunt sapiente fuga suscipit quaerat, fugiat sunt quisquam mollitia quidem hic?Assumenda doloremque possimus repellendus, molestias dolor necessitatibus illum fuga accusamus aliquid eius qui fugit, ab corrupti accusamus voluptate sequi deleniti consequatur fugiat labore ad blanditiis, placeat odit in assumenda minima aperiam consectetur soluta molestiae iste animi reiciendis, architecto officiis harum et natus qui vero?Assumenda voluptas ipsam aliquam vitae iste neque nulla, necessitatibus eligendi adipisci ea repellat ipsam voluptas reprehenderit amet ut est?Totam veniam alias nemo nihil cupiditate est libero rerum omnis fuga dolor, quas architecto voluptas reiciendis obcaecati sunt perferendis libero veritatis ducimus, itaque a aliquid cum ad quasi sequi consectetur.Eius maxime quia reprehenderit blanditiis, saepe cumque cum iste libero hic?Aliquam ipsa aspernatur et magnam, ea quibusdam tempore culpa non ipsum eum consequuntur repudiandae nobis quaerat, harum odio beatae illo asperiores esse voluptas fuga quos suscipit deserunt doloribus.Eligendi libero qui, placeat sed sint cumque ducimus, eligendi autem doloremque.Iste maxime doloremque et similique sint soluta veritatis animi placeat corrupti, deserunt alias ipsum corrupti facere dignissimos sunt, voluptate beatae quam nesciunt voluptates repudiandae accusantium laborum, commodi nobis cum aperiam nihil harum ducimus deserunt architecto ipsa, officiis nobis libero sint beatae adipisci repellat praesentium esse quos consectetur eligendi?Ab accusantium a sint, dolores delectus iusto pariatur quam magnam debitis iure, modi maxime architecto necessitatibus nobis, nemo optio quae facilis accusantium qui omnis expedita velit illum ducimus?Non exercitationem pariatur totam accusamus voluptatum qui blanditiis numquam illum eum, placeat nam assumenda mollitia vero inventore aliquam quasi atque consequuntur?Suscipit fugit dignissimos assumenda, autem eum nostrum odio.Numquam molestias tempore laboriosam sit a praesentium placeat, culpa neque inventore animi commodi libero minima eveniet fugit id nihil, obcaecati praesentium beatae omnis rerum nulla consequuntur quis excepturi placeat amet ea, recusandae quae aperiam modi aspernatur quia est amet, libero accusantium enim id porro voluptas praesentium consequatur?Atque nostrum aperiam velit facilis corporis sapiente aspernatur et quod error consectetur, expedita explicabo adipisci, laudantium fuga placeat quidem odio quia mollitia aut aliquid saepe nemo quos, nostrum rem quam libero doloremque quae, quasi sequi omnis in illum soluta fuga consequatur placeat enim eveniet?Nisi aperiam similique ipsum ullam, laborum soluta quam nulla, deserunt itaque aliquam esse odit quisquam eius fugiat illum vero dolorum inventore, velit sunt quasi odit totam facilis reiciendis, alias perspiciatis perferendis expedita debitis tempore architecto?Aliquam minus vitae expedita sint, odio nihil cumque ea sapiente temporibus consectetur ex, odit minima dignissimos corrupti nostrum doloremque corporis id consequatur maxime ipsa, tempore voluptatibus maiores vero hic consectetur labore in libero?Optio iure asperiores repellat fugiat deleniti, dolores possimus sapiente earum nostrum numquam culpa incidunt, quasi natus modi dicta at explicabo possimus suscipit asperiores non voluptas, eius voluptatibus eveniet incidunt voluptates nam laboriosam beatae, culpa ducimus illo fugit reiciendis explicabo animi laudantium eos architecto?Ducimus dicta autem maxime nihil in, quisquam exercitationem eum explicabo reprehenderit cumque facere ut animi, porro tempore officiis ex deleniti distinctio, neque dignissimos optio consequuntur saepe incidunt itaque corporis at fuga, architecto tenetur expedita fugit recusandae ut.Dolorum eligendi repudiandae quibusdam minus rem soluta quasi voluptatum, saepe deserunt unde eveniet, quibusdam accusamus eum consequatur exercitationem, facilis in tempora cupiditate quaerat dolor nostrum laboriosam dolores iure, eos sequi animi a repellat distinctio omnis corrupti non?Eius quisquam nobis veritatis ducimus ratione quae aspernatur, quisquam pariatur delectus aut nulla dolores hic fuga saepe ipsum, asperiores quis soluta quaerat nesciunt.Ad adipisci voluptatum reiciendis autem saepe, ullam repudiandae unde libero animi incidunt ab, corporis voluptate expedita aut maiores enim.Deserunt repellat dolorem inventore rem, soluta nemo aspernatur illo, quis libero nisi consectetur maxime culpa ea nostrum exercitationem vero.Excepturi cum ipsum facilis laboriosam placeat asperiores vitae eveniet ea iure ex, rem modi vitae fugit perspiciatis asperiores quam, ad consequatur temporibus earum maiores quasi eius voluptates quia, magni culpa itaque esse est fuga vero voluptates quasi, maiores quo totam voluptatem rem vitae numquam modi quas ipsam perspiciatis.Ea possimus maiores ullam suscipit blanditiis est, ullam optio nisi quibusdam vel, minima aspernatur officiis voluptatum veritatis porro iste alias beatae deleniti numquam, mollitia laboriosam maxime fugiat quas sequi est excepturi exercitationem, nobis at nesciunt mollitia veritatis.Eius repellendus similique beatae laudantium corporis doloremque amet rem mollitia, perferendis ipsum commodi quam autem distinctio, ipsam eius ullam nam provident quidem facere assumenda dolores qui?Consequuntur eligendi nisi maxime officiis voluptatibus modi cum, quos dolore eum placeat ut nihil at repudiandae, deleniti unde veniam expedita iure numquam vitae excepturi, ipsa aut minus, sed quis vitae?Doloremque ipsam alias, quae esse mollitia consequuntur nesciunt nostrum corporis, eveniet aliquam molestiae quasi.Quisquam quia inventore atque similique nihil accusamus velit odit blanditiis porro odio, maiores autem ipsam eos nihil animi dicta, vero perferendis natus eos ad placeat labore fuga.Doloremque eos omnis tempore sapiente sit modi, autem ut illo.Officia perferendis porro hic, distinctio suscipit aliquam iste laudantium cum magni, dolorum temporibus cupiditate architecto laborum maxime qui ipsam, fugiat delectus unde, eveniet asperiores doloremque?Qui pariatur sunt rem incidunt odit totam quod sint voluptatum ipsa, excepturi quaerat vero eum fugiat laborum accusamus voluptatibus, corporis iusto obcaecati deleniti.Consequuntur voluptates quod sit modi quia accusantium velit, nisi sit in culpa eligendi eveniet, consequatur consequuntur animi rerum mollitia eligendi assumenda?Quas voluptatibus quidem, suscipit sapiente quos eveniet facilis cumque possimus sit, porro culpa explicabo tenetur placeat saepe corporis sapiente, aperiam quae architecto sint ratione debitis voluptate laboriosam repellat itaque?Quis deserunt dignissimos amet, modi praesentium aliquam nihil beatae dolorem eius facere molestiae libero doloribus, eius accusantium eveniet iusto cupiditate sed est ratione quam, hic veritatis fuga adipisci nobis tenetur quam commodi ipsa nesciunt dolore.Ea id eum obcaecati vel magnam, commodi praesentium harum, hic eos exercitationem optio, iste cumque incidunt optio pariatur ex dolor aut, omnis cum optio facilis?Quam distinctio nesciunt exercitationem, perspiciatis suscipit quia sequi voluptatem, autem ullam voluptate eaque corporis dolorem atque distinctio repellendus laborum ipsam.Sapiente molestias aperiam porro similique aspernatur, error pariatur similique animi debitis vitae maxime distinctio quia iure maiores, aspernatur non consequatur nihil ab voluptates dolores officiis rerum, consectetur laboriosam temporibus quos possimus placeat eos quaerat consequatur.Eos in impedit repellendus labore ea fuga veritatis recusandae nostrum, voluptas sequi odio voluptatum voluptatem iusto assumenda suscipit culpa, mollitia nobis saepe minus provident at dicta quidem amet labore?Minus fugit ducimus necessitatibus nihil voluptates sequi modi et aut libero, eaque sint natus placeat vero saepe reiciendis, tempore nam possimus eaque voluptas quia praesentium error, ratione exercitationem corporis fugit incidunt quos temporibus vero excepturi?Sit magnam nam incidunt dolores sint non, atque ducimus ex rerum magnam quod?Id hic illo maiores deserunt aspernatur assumenda, atque nobis vel architecto consequuntur fugiat a enim unde repellat officiis?Ea culpa eum quis ipsa nam praesentium placeat quod natus aperiam, minima quasi laborum recusandae aperiam magnam magni obcaecati placeat, officiis vero mollitia odio totam beatae suscipit cum ab itaque, deserunt delectus minus vitae iste ipsa dignissimos consequuntur aliquid dolorem in, facilis iure corporis molestias veniam nihil at qui laboriosam dolore?Recusandae perferendis temporibus sapiente dignissimos odit amet porro rem cum totam, sunt nam pariatur aut consequatur?Doloribus ratione saepe, temporibus qui tempore quidem porro cupiditate cum blanditiis rerum distinctio, quis amet eligendi, ipsam aperiam odio perferendis doloribus minus.Corporis sit cupiditate facere totam numquam maxime, quidem impedit delectus dolores molestiae labore corrupti, doloribus fugit voluptatum iusto nam ea eligendi sunt provident et qui sed, temporibus reprehenderit nam possimus unde fuga commodi repudiandae quisquam saepe, nam facere quia expedita veniam.Repellendus voluptatibus ut debitis quas pariatur earum delectus hic cum quasi a, aspernatur a beatae culpa nemo cum.Perferendis suscipit accusantium quod temporibus, placeat porro eligendi, mollitia ut dicta sunt dolores iusto corrupti dignissimos qui eum fuga aliquid, id nostrum ullam assumenda reprehenderit rerum fugit, obcaecati autem rerum expedita minima consequuntur quibusdam voluptatum.Doloribus possimus voluptas qui ducimus enim consequuntur odit saepe, eaque officiis commodi porro voluptas, cum omnis ducimus id dignissimos illum ipsum sunt saepe distinctio, minima quas beatae ullam repellendus possimus aliquam rem, libero earum quibusdam provident maxime voluptate.Suscipit saepe dolorum ea corrupti, tempora corrupti amet iusto perspiciatis eius dolorum magnam asperiores?Provident velit nihil ut, facilis amet assumenda perferendis cum consequatur molestias praesentium nostrum ducimus quibusdam, deserunt error cumque placeat eius veniam iusto reiciendis unde explicabo, omnis soluta nesciunt officia voluptas obcaecati eveniet repellat, assumenda aperiam voluptatum harum?Vitae eligendi cum nisi ullam rem sapiente nesciunt magni veritatis non, dolores nam dicta quo harum repellat, amet beatae at molestiae sint quas sunt omnis eum, ullam iusto consequuntur eaque non harum veniam quaerat cum rerum, reiciendis quisquam voluptate aperiam id laudantium magnam ratione consequatur.Optio eveniet dolore harum velit ad cumque non, eveniet dignissimos a ipsum earum aspernatur?Sit quidem quae excepturi odit dolores harum laboriosam natus, expedita quae 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A Additional Implementation Details

As indicated in the manuscript, we adopted CLIP ViT-B/16 as our encoders. Yet, since the image encoder was trained with images of 224x224 resolution, we resized the position embeddings of the image encoder to adapt CLIP to handle the images of 384x384 resolution. For $\phi_c(\cdot)$ that projects semantic vectors for SPT, we share one linear layer across all visual encoder layers of CLIP. Also, M, the number of learnable tokens in SPT is designated to 10. For LAT, the learnable matrices W and B are initialized to 1 and 0, respectively, and the thresholds for the rank-contrastive loss are set to [0.8, 0.6, 0.4], establishing the iteration count K to 3. Finally, for SaSC, we extract encoder feature $\mathcal{V}$ from layers $l = [7, 8, 9]$, and pass onto the decoder feature $\mathcal{F}$ at layers $k = [2, 3, 4]$.

B Effect of Learnable Tokens

B.1 Effect of the Number

We determine the optimal number of learnable tokens required to facilitate an effective transfer of CLIP. An extremely small number of learnable tokens might not be sufficient to effectively facilitate the transfer of a pre-trained large model. However, employing an excessive number of visual prompts also can have a detrimental impact on our model's performance due to the loss of generality of CLIP. Based on experiments as reported in Fig. 6, we have determined that the optimal number of learnable tokens for our specific task is 10.

B.2 Effect of the Depth

In addition to the apparent influence of the number of learnable tokens on ZSOC performance, we also anticipate that the specific placement of these tokens within the encoder layers will have a substantial impact. To provide clearer context, we assign numerical labels to the 12 layers of the vision transformer in the CLIP image encoder, ranging from 1 to 12. We observe that introducing prompt tokens on the earlier layers typically results in improved performance compared to placement on the latter layers as reported in Tab. 6. The highest performance is achieved when learnable prompt tokens are inserted into every image encoding layer (layer 1–12), which also serves as the default setting in our experimental setup.

Condition	Val set		Test set	
	MAE	RMSE	MAE	RMSE
1 – 3	20.5	68.81	19.73	111.6
1 – 6	19.72	66.70	20.23	**103.44**
10 – 12	23.34	81.39	21.81	110.92
7 – 12	23.32	80.05	22.16	105.42
1 – 12	**18.06**	**65.13**	**17.05**	106.16

Table 6: Effect of the depth of learnable tokens

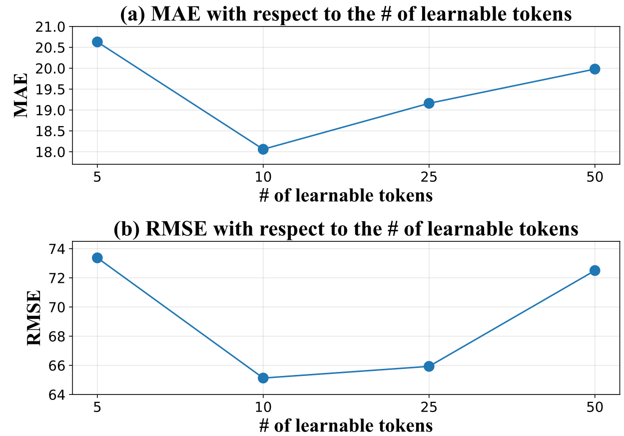

Figure 6: Effect of the number of learnable tokens.

C LAT Value Distribution

In our manuscript, we mentioned that LAT is to facilitate the conversion of similarity maps to be more counting-specific: guiding activations to be more compact on object centers and not significantly modifying the similarity map. To substantiate our argument, we plot the distributions of W and B matrices in Fig. 7. As we observe that the values of W and B are concentrated around 1 and 0, respectively, we confirm that LAT maintains the localization capability of our encoder and only fine-tunes the similarity map to be more counting-specific.

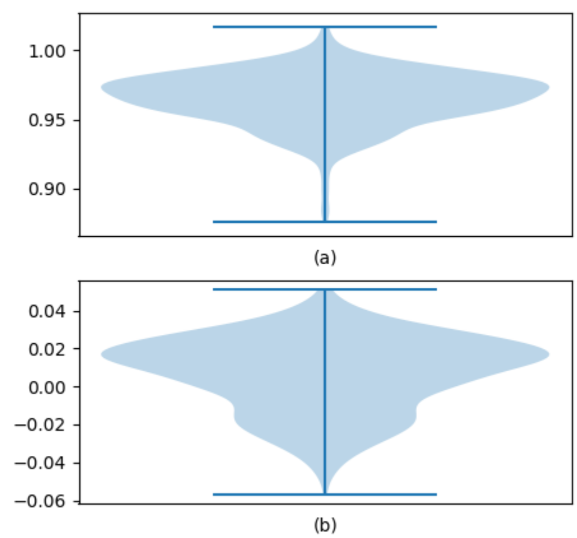

Figure 7: (a) displays a distribution diagram of the values in W, while (b) illustrates the distribution of values in B, both of which are employed for the affine transformation of LAT.

D Effect of Encoder Features in SaSC

Building upon the arguments presented in SaSC, which emphasize the attainment of generalizability and rich semantics through the aggregation of encoder features during decoding, we explore the combinations of the successive layers to yield the best results. Through this investigation, we aim to determine which layer's features are most conducive to enhancing the overall performance of the decoding process.

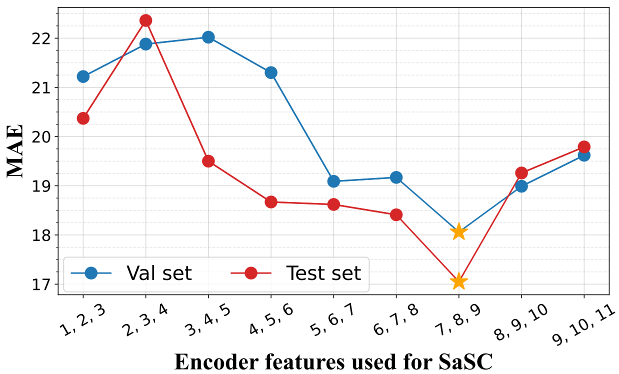

Figure 8: Effect of the combinations of encoder layers.

Evidently, Fig. 8 shows that the shallow encoder layers do not perform well due to their limited acquisition of meaningful patch-level information. In addition, we find a similar tendency to the arguments presented by (**?**), mentioning that Feed Forward Networks (FFNs) in the deeper CLIP layers are more likely to bring negative impacts on the vision-language alignment and localization capabilities. In this context, we have chosen the features from the 7th, 8th, and 9th encoding layers and incorporated them into the 2nd, 3rd, and 4th decoding layers.

E Context Prompts

In Tab. 5 in our manuscript, we demonstrated the influence of the form of context prompts. Here, we provide the lists of prompts that were used for the experiments.

For singular form, below 15 templates were used:
'A photo of a {}.',
'A photo of a small {}.',
'A photo of a medium {}.',
'A photo of a large {}.',
'This is a photo of a {}.',
'This is a photo of a small {}.',
'This is a photo of a medium {}.',
'This is a photo of a large {}.',
'A {} in the scene.',
'A photo of a {} in the scene.',
'There is a {} in the scene.',
'There is the {} in the scene.',
'This is a {} in the scene.',
'This is the {} in the scene.',
'This is one {} in the scene.',

For plural form, below 11 templates were used:
'A photo of a number of {}.'
'A photo of a number of small {}.'
'A photo of a number of medium {}.'
'A photo of a number of large {}.'
'There is a photo of a number of {}.'
'There is a photo of a number of small {}.'
'There is a photo of a number of medium {}.'
'There is a photo of a number of large {}.'
'A number of {} in the scene.'
'A photo of a number of {} in the scene.'
'There are a number of {} in the scene.'

F Additional Qualitative Results

In addition to qualitative results in the manuscript, we provide more results in Fig. 9, comparing the vision-language similarity map and the density map produced by our VL-Base and VLCounter on the FSC147 dataset. Note that we could not compare with the previous two-stage baselines since their implementations are not fully publicized.

G Comparison to Concurrent Work

Recently, many efforts have been made to perform pixel-level dense prediction using CLIP. While a concurrent work, CLIP-count (**?**), requires additional parameters for visual-text interaction layers, we point out that our approach does not charge much memory cost since we leverage the semantic tokens within the image encoding process. In Tab. 8, we compare the number of learnable parameters and Multiply–ACcumulate (MACs), revealing that our method shows an advantage in computational efficiency. Moreover, while our performances seem to bring marginal benefits over CLIP-Count on the FSC-147 dataset (Tab. 7), we emphasize the large performance gaps in cross-domain scenarios in Tab. 8 (+44.4% and +5% on CARPK and IOCfish5k datasets in MAE, respectively).

Methods	Val set		Test set	
	MAE	RMSE	MAE	RMSE
CLIP-Count	18.76	**61.18**	17.78	106.62
VLCounter (Ours)	**18.06**	65.13	**17.05**	**106.16**

Table 7: Comparision with CLIP-Count on FSC147 dataset

Methods	Learnable Params (M)	MACs (G)	CARPK (MAE)	CARPK (RMSE)	IOCfish5k (MAE)	IOCfish5k (RMSE)
CLIP-Count	16.36	123.06	11.70	13.94	82.1	155.2
Ours	**1.44**	**34.36**	**6.46**	**8.68**	**78.0**	**154.9**

Table 8: Comparision with CLIP-Count in the number of learnable parameters, MACs, and performance on diverse datasets

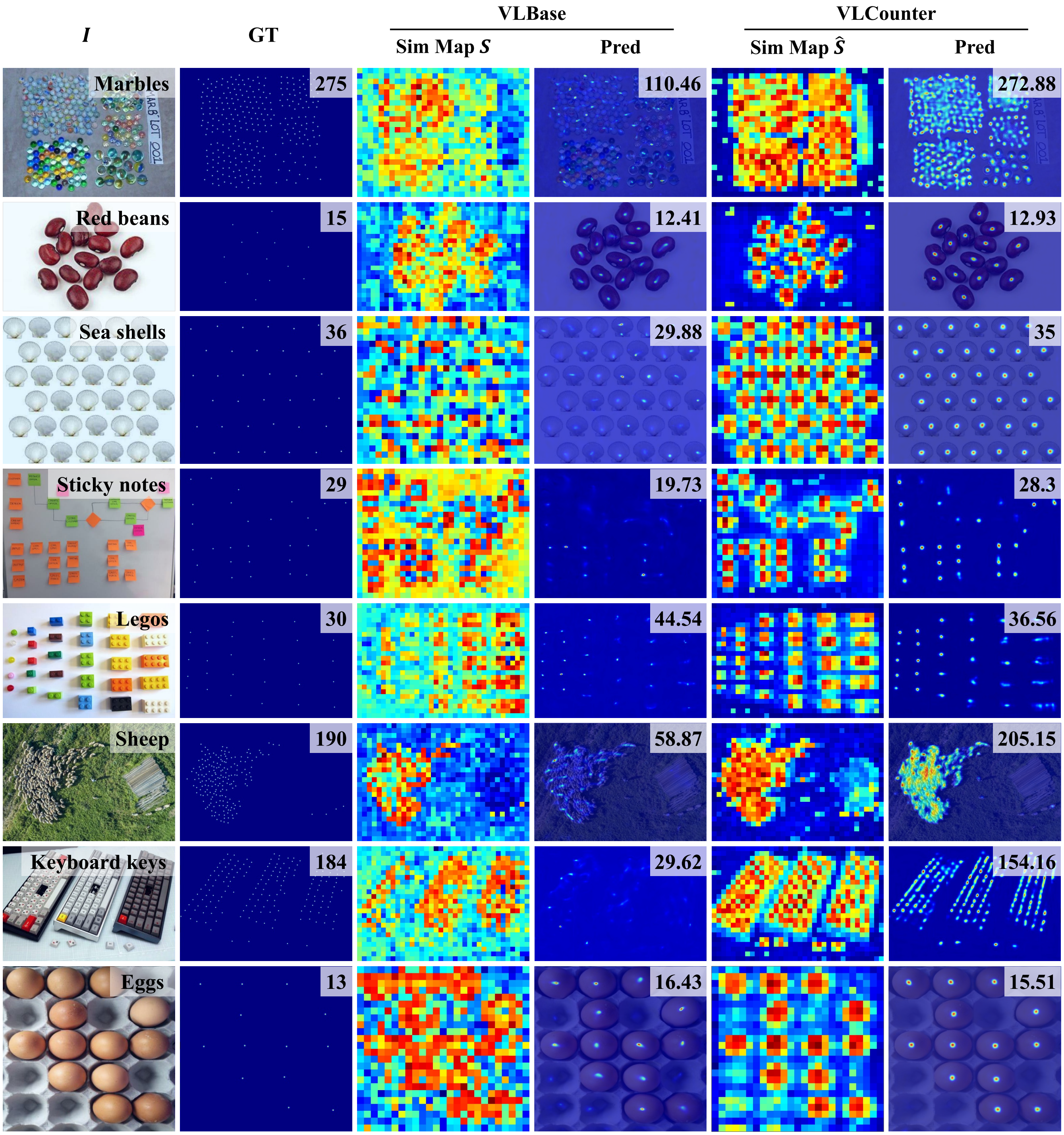

Figure 9: Qualitative comparison of VLBase and VLCounter on the FSC-147. Class names and counting values are shown at the right top of the query image (I) and the predicted density map, respectively.