

# ForAug: Recombining Foregrounds and Backgrounds to Improve Vision Transformer Training with Bias Mitigation

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## Abstract

Transformers, particularly Vision Transformers (ViTs), have achieved state-of-the-art performance in large-scale image classification. However, they often require large amounts of data and can exhibit biases that limit their robustness and generalizability. This paper introduces *ForAug*, a novel data augmentation scheme that addresses these challenges and explicitly includes inductive biases, which commonly are part of the neural network architecture, into the training data. *ForAug* is constructed by using pretrained foundation models to separate and recombine foreground objects with different backgrounds, enabling fine-grained control over image composition during training. It thus increases the data diversity and effective number of training samples. We demonstrate that training on *ForNet*, the application of *ForAug* to ImageNet, significantly improves the accuracy of ViTs and other architectures by up to 4.5 percentage points (p.p.) on ImageNet and 7.3 p.p. on downstream tasks. Importantly, *ForAug* enables novel ways of analyzing model behavior and quantifying biases. Namely, we introduce metrics for background robustness, foreground focus, center bias, and size bias and show that training on *ForNet* substantially reduces these biases compared to training on ImageNet. In summary, *ForAug* provides a valuable tool for analyzing and mitigating biases, enabling the development of more robust and reliable computer vision models. Our code and dataset are publicly available at [<url>](#).

## 1 Introduction

Image classification, a fundamental task in computer vision (CV), involves assigning labels to images from a set of categories. It underpins a wide range of applications, like medical diagnosis (Sanderson and Matuszewski 2022; Vezakis et al. 2024), autonomous driving (Wang et al. 2022b), and object recognition (Carion et al. 2020; He et al. 2017; Girshick et al. 2013) and facilitates large-scale pretraining (Dosovitskiy et al. 2021; Liu et al. 2021; Touvron et al. 2021), and progress evaluation in CV (Khan et al. 2022; Rangel et al. 2024). The advent of large-scale datasets, particularly ImageNet (Deng et al. 2009), served as a catalyst for the rise of large-scale CV models (Krizhevsky, Sutskever, and Hinton 2012; He et al. 2016) and remains the most important CV benchmark for more than a decade (Krizhevsky, Sutskever, and Hinton 2012; Touvron, Cord, and Jégou 2022; Wortsman et al. 2022; He et al. 2016). While traditionally, convolutional neural networks (CNNs) have been the go-to architecture

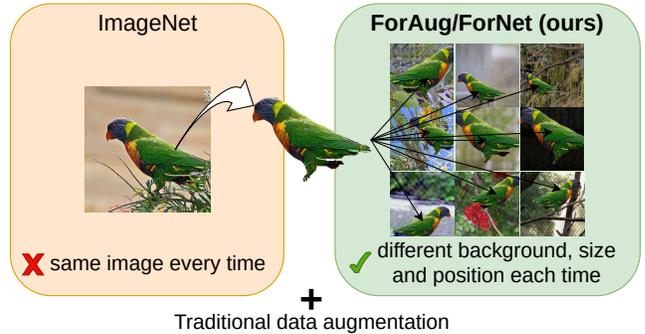


Figure 1: Comparison of *ForNet* and ImageNet. *ForNet* recombines foreground objects with different backgrounds each epoch, thus creating a more diverse training set. We still apply traditional data augmentation afterwards.

in CV, Transformers (Vaswani et al. 2017), particularly the Vision Transformer (ViT) (Dosovitskiy et al. 2021), have emerged as a powerful alternative, demonstrating superior performance in various vision tasks, including image classification (Wortsman et al. 2022; Yu et al. 2022; Carion et al. 2020; Zong, Song, and Liu 2022; Wang et al. 2022a).

Data augmentation is a key technique for training image classification models. Traditional data augmentation methods, such as random cropping, flipping, and color changes, are commonly employed to increase the diversity of the training data and improve the model’s performance (Xu et al. 2023; Shorten and Khoshgoftaar 2019). These basic transformations, originally designed for CNNs, change the input images in a way that preserves their semantic meaning (Alomar, Aysel, and Cai 2023), but are limited to existing image compositions. While combinations of these data augmentations are still used today, they originally were proposed to benefit CNNs. However, the architectural differences of CNNs and Transformers suggest that the latter might benefit from different data augmentation strategies. In particular, the Transformers self-attention mechanism, unlike a CNN, is not translation equivariant (Rojas-Gomez et al. 2023; Ding et al. 2023), meaning that the model does not understand the spatial relationships between pixels by design.

Recognizing that Transformers need to learn the spatial relationships from data, we propose *ForAug*, a novel data aug-

mentation scheme that recombines foreground objects with different backgrounds. Thus, *ForAug* goes beyond existing image compositions and encodes desired invariances directly into the training data (see Figure 1). Applying *ForAug* to ImageNet gives rise to *ForNet*, a novel dataset that enables this data augmentation with with fine-grained control over the image composition. We separate the foreground objects in ImageNet from their backgrounds, using an open-world object detector (Ren et al. 2024), and fill in the background in a plausible way using an object removal model (Sun et al. 2024; Suvorov et al. 2021). This allows us to then recombine any foreground object with any background on the fly, creating a highly diverse training set. During recombination, we can control important parameters, like the size and position of the foreground object, to help the model learn the spatial invariances necessary for image classification. We show that training on *ForNet* instead of ImageNet increases the model accuracy of Transformers by up to 4.5 p.p. on ImageNet and an up to 39.3% reduction in error rate on downstream tasks.

On top of that, *ForAug* is a useful tool for analyzing model behavior and biases, when used during evaluation. We utilize our control over the image distribution to measure a model’s background robustness (by varying the choice of background), foreground focus (by leveraging our knowledge about the placement of the foreground object), center bias (by controlling position), and size bias (by controlling size). These analyses provide valuable insights into model behavior and biases, which is crucial for model deployment and future robustness optimizations. We show that training on *ForNet*, instead of ImageNet, significantly reduces all of these biases. We make our code for *ForAug* and the *ForNet*-dataset publicly available<sup>1</sup> to facilitate further research.

## Contributions

- We propose *ForAug*, a novel data augmentation scheme, that recombines objects and backgrounds. *ForAug* allows us to move beyond the (possibly biased) image compositions in the dataset while preserving label integrity.
- We show that training ViT on *ForNet*, the ImageNet instantiation of *ForAug*, leads to up to 4.5 p.p. improved accuracy on ImageNet and 7.3 p.p. on downstream tasks.
- We propose novel *ForAug*-based metrics to analyze and quantify fine-grained biases of trained models: Background Robustness, Foreground Focus, Center Bias, and Size Bias. We show that training on *ForNet*, instead of ImageNet, significantly reduces these biases.

## 2 Related Work

**Data Augmentation for Image Classification** Data augmentation is a crucial technique for improving the performance and generalization of image classification models. Traditional augmentation strategies rely on simple geometric or color-space transformations like cropping, flipping, roatation, blurring, color jittering, or random erasing (Zhong et al. 2017) to increase the diversity of the training data without changing their semantic meaning. With the advent of Transformers,

new data augmentation operations like PatchDropout (Liu et al. 2022) have been proposed. Other transformations like Mixup (Zhang et al. 2018), CutMix (Yun et al. 2019), or random cropping and patching (Takahashi, Matsubara, and Uehara 2018) combine multiple input images. These simple transformations are usually bundled to form more complex augmentation policies like AutoAugment (Cubuk et al. 2018) and RandAugment (Cubuk et al. 2019), or 3-augment (Touvron, Cord, and Jégou 2022) which is optimized to train a ViT. For a general overview of data augmentation techniques for image classification, we refer to (Shorten and Khoshgoftaar 2019; Xu et al. 2023).

We build upon these general augmentations by introducing a novel approach to explicitly separate objects and backgrounds for image classification, allowing us to – unlike these basic transforms – move beyond dataset image compositions. Our approach is used in tandem with traditional techniques to improve performance and reduce biases.

**Copy-Paste Augmentation** The copy-paste augmentation (Ghiasi et al. 2020), which is used for object detection (Shermaine, Lazarou, and Stathaki 2025; Ghiasi et al. 2020) and instance segmentation (Werman 2021; Ling, Huang, and Hur 2022), involves copying segmented objects from one image and pasting them onto another. While typically human annotated segmentation masks are used to extract the foreground objects, other foreground sources have been explored, like 3D models (Hinterstoisser et al. 2019) and pretrained object-detection models for use on objects on white background (Dwibedi, Misra, and Hebert 2017) or synthetic images (Ge et al. 2023). (Kang and Chung) apply copy-paste as an alternative to CutMix in image classification, but they do not shift the size or position of the foregrounds and use normal dataset images as backgrounds.

While these methods paste objects onto another image (with a different foreground) or on available or rendered background images of the target scene, we extract foreground objects and fill in the resulting holes in the background in a semantically neutral way. This way, we are preserving label integrity while also having diverse, neutral backgrounds available for recombination, enabling a controlled and diverse manipulation of image composition.

**Model robustness evaluation** Evaluating model robustness to various image variations is critical for understanding and improving model generalization. Datasets like ImageNet-C (Hendrycks and Dietterich 2019) and ImageNet-P (Hendrycks and Dietterich 2019) introduce common corruptions and perturbations. ImageNet-E (Li et al. 2023) evaluates model robustness against a collection of distribution shifts. Other datasets, such as ImageNet-D (Zhang et al. 2024), focus on varying background, texture, and material, but rely on synthetic data. Stylized ImageNet (Geirhos et al. 2018) investigates the impact of texture changes. ImageNet-9 (Xiao et al. 2020) explores background variations using segmented images, but the backgrounds are often artificial.

In contrast to these existing datasets, which are used only for evaluation, *ForNet* provides fine-grained control over foreground object placement, size, and background selection, enabling a precise and comprehensive analysis of specific model

<sup>1</sup>Link will go here.

biases within the context of a large-scale, real-world image distribution. As *ForNet* also provides controllable training set generation, it goes beyond simply measuring robustness to actively improving it through training.

### 3 ForAug (Method)

We introduce *ForAug*, a data augmentation scheme designed to enhance Transformer training by explicitly separating and recombining foreground objects and backgrounds. *ForAug* involves two stages: Segmentation and Recombination, both visualized in Figure 2.

**Segmentation** The segmentation stage isolates the foreground objects and their corresponding backgrounds. We then fill in the background in a visually plausible way (Sun et al. 2024) using a pretrained object-removal model. This stage is computed once offline and the results are stored for the recombination stage.

First, foreground objects are detected and segmented from their backgrounds using a prompt-based segmentation model to exploit the classification datasets labels. We use the state-of-the-art Grounded SAM (Ren et al. 2024), which is based on Grounding DINO (Liu et al. 2023) and SAM (Kirillov et al. 2023). The prompt we use is “a `<class name>`, a type of `<object category>`”, where `<class name>` is the specific name of the objects class as defined by the dataset and `<object category>` is a the broader category of the object. The `<object category>` guides the segmentation model towards the correct object in case the `<class name>` alone is too specific. This can be the case with prompts like “sorrel” or “guenon”, where the more general name “horse” or “monkey” is more helpful. We derive the `<object category>` from the WordNet hierarchy, using the immediate hyponym.

We iteratively extract up to  $n$  foreground masks for each dataset-image, using different more and more general prompts based on the more general synsets of WordNet (e.g. “a sorrel, a type of horse”, “a horse, a type of equine”, ...). Masks that are very similar, with a pairwise IoU of at least 0.9, are merged. The output is a set of masks delineating the foreground objects and the backgrounds. We select the best mask per image (according to Equation (1)) in a later filtering step, described below.

An inpainting model that is specifically optimized to remove objects from images, such as LaMa (Suvorov et al. 2021) or Attentive Eraser (Sun et al. 2024), is used to inpaint the foreground regions in the backgrounds. To ensure the quality of the foreground and background images (for each dataset-image), we select a foreground/background pair from the  $\leq n$  variants we have extracted and infilled in the previous steps. Using an ensemble of six ViT, ResNet, and Swin Transformer models pretrained on the original dataset, we select the foreground/background pair that maximizes foreground performance while minimizing the performance

on the background and size of the foreground according to:

$$\begin{aligned} \text{score}(\text{fg}, \text{bg}, c) = & \log \left( \frac{1}{|E|} \sum_{m \in E} \mathbb{P}[m(\text{fg}) = c] \right) \\ & + \log \left( 1 - \frac{1}{|E|} \sum_{m \in E} \mathbb{P}[m(\text{bg}) = c] \right) \quad (1) \\ & + \lambda \log \left( 1 - \left| \frac{\text{size}(\text{fg})}{\text{size}(\text{bg})} - \varepsilon \right| \right). \end{aligned}$$

Here,  $E$  is the ensemble of models and  $m$  is a pretrained model,  $c$  is the correct foreground class, fg, and bg are the foreground and background and  $\text{size}(\cdot)$  is the size in number of pixels. We ran a hyperparameter search using a manually annotated subset of foreground/background variants to find the factors in Equation (1):  $\lambda = 2$  and  $\varepsilon = 0.1$ . This filtering step ensures we segment all the relevant foreground objects.

Finally, we filter out backgrounds that are largely infilled, as these tend to be overly synthetic and don’t carry much information (see the supplementary material). In summary, we factorize the dataset into a set of foreground objects with a transparent background and a set of diverse backgrounds per class. The next step is to recombine these, before applying other common data augmentation operations during training.

**Recombination** The recombination stage, performed online during training, combines the foreground objects with different backgrounds to create new training samples. For each object, we follow the pipeline of: Pick an appropriate background, resize it to a fitting size, and place it in the background image. Through this step, we expose the model to variations beyond the image compositions of the dataset.

For each foreground object, we sample a background using one of the following strategies: (1) the original image background, (2) the set of backgrounds from the same class, or (3) the set of all possible backgrounds. These sets are trading off the amount of information the model can learn from the background against the diversity of new images created. In each epoch, each foreground object is seen exactly once, but a background may appear multiple times.

The selected foreground is resized based on its relative size within its original image and the relative size of the original foreground in the selected background image. The final size is randomly selected from a 30% range around upper and lower limits ( $s_u$  and  $s_l$ ), based on the original sizes. To balance the size of the foreground and that of the backgrounds original foreground, the upper and lower limit  $s_u$  and  $s_l$  are set to the mean or range of both sizes, depending on the foreground size strategy: *mean* or *range*.

The resized foreground is then placed at a random position within the background image. This position is sampled from a generalization of the Bates distribution (Bates 1955) with parameter  $\eta \in \mathbb{Z}$ . We choose the bates distribution, as it presents an easy way to sample from a bounded domain with just one hyperparameter that controls the concentration of the distribution.  $\eta = 1/ - 1$  corresponds to the uniform distribution;  $\eta > 1$  concentrates the distribution around the center; and for  $\eta < -1$ , the distribution is concentrated at the borders. To more seamlessly integrate the foreground, we

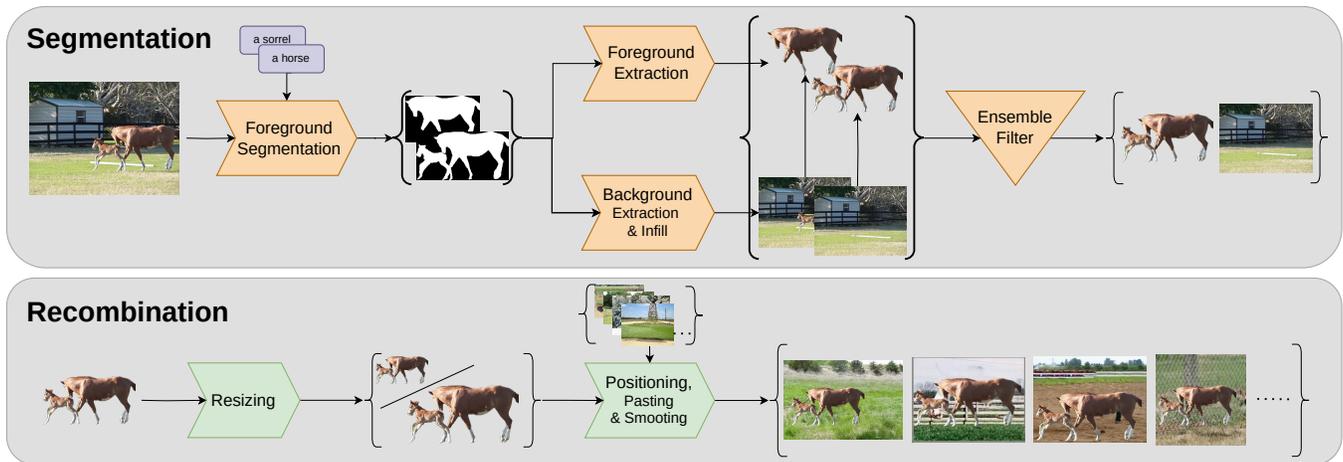


Figure 2: Overview of *ForNet*. The data creation consists of two stages: (1, offline) Segmentation, where we segment the foreground objects from the background and fill in the background. (2, online) Recombination, where we combine the foreground objects with different backgrounds to create new samples.

apply a Gaussian blur with  $\sigma \in [\frac{\sigma_{\max}}{10}, \sigma_{\max}]$ , inspired by the standard range for the Gaussian blur operation in (Touvron, Cord, and Jégou 2022), to the foreground’s alpha-mask.

We can apply standard data augmentation techniques in two modes: Either we apply all augmentations to the recombined image, or we apply the cropping and resizing to the background only and then apply the other augmentations after recombination. The second mode ensures the foreground object remains fully visible, while the first mode mirrors standard data augmentation practices.

We experiment with a constant mixing ratio, or a linear or cosine annealing schedule that increases the amount of images from the original dataset over time. The mixing ratio acts as a probability of selecting an image from the original dataset; otherwise, an image with the same foreground is recombined using *ForAug*, ensuring each object is seen once per epoch.

## 4 Experiments

We conduct a comprehensive suit of experiments to validate the effectiveness of our approach. We compare training on *ForNet*, the ImageNet instantiation of *ForAug*, to training on ImageNet for 10 different models. Furthermore, we assess the impact of using *ForNet* for pretraining on multiple fine-grained downstream datasets. Additionally, we use *ForAug*’s control over the image distribution to quantify some model behaviors and biases. We always report the mean and standard deviation of three independent training runs.

### 4.1 Design Choices of *ForAug*

We start by ablating the design choices of *ForAug*. For this, we revert to TinyImageNet (Le and Yang 2015), a subset of ImageNet containing 200 categories with 500 images each, and *TinyForNet*, a version of *ForAug* derived from TinyImageNet. Table 1 presents the ablations for the segmentation phase and Table 2 for the recombination phase.

**Prompt.** First, we evaluate the type of prompt used to detect the foreground object. Here, the *general* prompt, which

Dataset	Detect. Prompt	Infill Model	TinyImageNet Accuracy [%]	
			ViT-Ti	ViT-S
TinyImageNet			66.1 ± 0.5	68.3 ± 0.7
<i>TinyForNet</i>	specific	LaMa (Suvorov et al. 2021)	65.5 ± 0.4	71.2 ± 0.5
<i>TinyForNet</i>	general	LaMa (Suvorov et al. 2021)	66.4 ± 0.6	72.9 ± 0.6
<i>TinyForNet</i>	general	Att. Eraser (Sun et al. 2024)	67.5 ± 1.2	72.4 ± 0.5

Table 1: Ablation of the design decisions in the segmentation phase of *ForAug* on TinyImageNet.

contains the class and the more general object category, outperforms only having the class name (*specific*).

**Inpainting.** Attentive Eraser (Sun et al. 2024) produces superior results compared to LaMa (Suvorov et al. 2021) (see the supplementary material for examples).

**Foreground size** significantly impacts performance. Employing a *range* of sizes during recombination, rather than a fixed *mean* size, boosts accuracy by approximately 1 p.p. This suggests that the added variability is beneficial.

**Order of data augmentation.** Applying all augmentations after foreground-background recombination (*paste*→*crop*→*color*) slightly improves ViT-S’s performance compared to applying crop-related augmentations before pasting (*crop*→*paste*→*color*). For ViT-Ti, results are ambiguous.

**Background pruning.** When it comes to the choice of backgrounds to use, we test different pruning thresholds ( $t_{\text{prune}}$ ) to exclude backgrounds with excessive inpainting. A threshold of  $t_{\text{prune}} = 1.0$  means that we use all backgrounds that are not fully infilled. Varying  $t_{\text{prune}}$  has minimal impact. Therefore, we choose  $t_{\text{prune}} = 0.8$  to exclude predominantly artificial backgrounds.

**Mixing *ForNet*** with the original ImageNet data proves crucial. While constant and linear mixing schedules improve performance over no mixing by 2 – 3 p.p. compared to only using *TinyForNet*, the cosine annealing schedule yields the best results, boosting accuracy by 3 – 4 p.p.

**Edge smoothing.** We evaluate the impact of using Gaus-

FG size	Augment. Order	BG Strat.	BG. Prune	Original Mixing	Edge Smooth.	Accuracy [%]	
						ViT-Ti	ViT-S
<b>TinyImageNet</b>						66.1 ± 0.5	68.3 ± 0.7
mean	crop→paste	same	-	-	-	64.6 ± 0.5	70.0 ± 0.6
range	crop→paste	same	-	-	-	65.5 ± 0.4	71.2 ± 0.5
range	crop→paste	same	-	-	-	67.5 ± 1.2	72.4 ± 0.5
range	paste→crop	same	-	-	-	67.1 ± 1.2	72.9 ± 0.5
range	paste→crop	same	1.0	-	-	67.0 ± 1.2	73.0 ± 0.3
range	paste→crop	same	0.8	-	-	67.2 ± 1.2	72.9 ± 0.8
range	paste→crop	same	0.6	-	-	67.5 ± 1.0	72.8 ± 0.7
range	paste→crop	same	0.8	$p = 0.2$	-	69.8 ± 0.5	75.0 ± 0.3
range	paste→crop	same	0.8	$p = 0.33$	-	69.5 ± 0.4	75.2 ± 1.0
range	paste→crop	same	0.8	$p = 0.5$	-	70.3 ± 1.0	74.2 ± 0.2
range	paste→crop	same	0.8	linear	-	70.1 ± 0.7	74.9 ± 0.8
range	paste→crop	same	0.8	reverse lin.	-	67.6 ± 0.2	73.2 ± 0.3
range	paste→crop	same	0.8	cos	-	71.3 ± 1.0	75.7 ± 0.8
range	paste→crop	same	0.8	cos	$\sigma_{\max} = 4.0$	70.0 ± 0.8	75.5 ± 0.7
range	paste→crop	orig.	0.8	cos	$\sigma_{\max} = 4.0$	67.2 ± 0.9	69.9 ± 1.0
range	paste→crop	all	0.8	cos	$\sigma_{\max} = 4.0$	70.1 ± 0.7	77.5 ± 0.6
<b>ImageNet</b>						-	79.1 ± 0.1
range	paste→crop	same	0.8	cos	-	-	80.5 ± 0.1
range	paste→crop	same	0.8	cos	$\sigma_{\max} = 4.0$	-	80.7 ± 0.1
range	paste→crop	all	0.8	cos	$\sigma_{\max} = 4.0$	-	81.4 ± 0.1

Table 2: Ablation of the recombination phase of *ForAug* on TinyImageNet (top) and ImageNet (bottom). The first experiments use the initial segmentation settings.

Training Set/ Bates Parameter	TIN	TinyForNet				
		$\eta = -3$	-2	1/ - 1	2	3
TinyImageNet	68.9	60.5	60.2	60.8	62.6	63.1
$\eta = -3$	71.3	79.3	79.5	79.1	79.3	79.1
$\eta = -2$	71.5	80.0	78.7	79.3	79.1	78.8
$\eta = 1/ - 1$	72.3	79.5	78.9	80.2	79.7	80.4
$\eta = 2$	71.3	78.2	77.8	79.1	79.6	79.9
$\eta = 3$	71.4	77.2	76.9	78.6	79.6	79.7

Table 3: Accuracy of ViT-S trained on TinyImageNet (TIN) and TinyForNet with different foreground position distributions by varying the Bates parameter  $\eta$ . The best performance is achieved using the uniform distribution ( $\eta = 1$ ).

sian blurring to smooth the edges of the foreground masks. For larger models, this gives us a slight performance boost, especially on the full *ForNet*.

**Background strategy.** Another point is the allowed choice of background image for each foreground object. We compare using the original background, a background from the same class, and any background. These strategies go from low diversity and high shared information content between the foreground and background to high diversity and low shared information content. For *ViT-Ti*, the latter two strategies perform comparably, while *ViT-S* benefits from the added diversity of using any background. The same is true when training on the full (ImageNet) version of *ForNet*.

**Foreground position.** Finally, we analyze the foreground object’s positioning in the image. We utilize an extended Bates distribution to sample the position of the foreground object. The larger  $\eta$ , the more concentrated the distribution is around the center,  $\eta < -1$  concentrate the distribution at the edges. When sampling more towards the center of the image, the difficulty of the task is reduced, which then reduces the performance on TinyImageNet (see Table 3). This is reflected in the performance when evaluating on TinyForNet with  $\eta = 2$  and  $\eta = 3$  compared to  $\eta = -1/1$ . We observe a similar reduction for  $\eta < -1$ .

Dataset	Classes	Training Images	Validation Images
TinyImageNet	200	100,000	10,000
TinyForNet	200	99,404	9,915
ImageNet	1,000	1,281,167	50,000
ForNet	1,000	1,274,557	49,751

Table 4: Dataset statistics for TinyImageNet, TinyForNet, ImageNet, and *ForNet*. For *ForNet* and TinyForNet we report the number of foreground/background pairs.

Model	ImageNet Accuracy when trained on		Delta
	ImageNet	ForNet	
ViT-S	79.1 ± 0.1	81.4 ± 0.1	+2.3
ViT-B	77.6 ± 0.2	81.1 ± 0.4	+3.5
ViT-L	75.3 ± 0.4	79.8 ± 0.1	+4.5
DeiT-S	80.1 ± 0.1	80.0 ± 0.3	-0.1
DeiT-B	81.9 ± 0.3	81.9 ± 0.2	±0.0
DeiT-L	79.3 ± 2.3	82.4 ± 0.1	+3.1
Swin-Ti	77.9 ± 0.2	79.7 ± 0.1	+1.8
Swin-S	79.4 ± 0.1	80.6 ± 0.1	+1.2
ResNet-50	78.3 ± 0.1	78.8 ± 0.1	+0.5
ResNet-101	79.4 ± 0.1	80.4 ± 0.1	+1.0

Table 5: ImageNet results of models trained on *ForNet* and on ImageNet directly. *ForAug/ForNet* improves the performance of all models in our test.

After fixing the optimal design parameters in Tables 1 and 2 (last rows), we construct the full *ForNet* dataset using the entire ImageNet dataset. Table 4 compares the dataset statistics of ImageNet and *ForNet*. The slightly reduced image count in *ForNet* is due to instances where Grounded SAM fails to produce valid object detections.

## 4.2 Image Classification Results

Table 5 compares the ImageNet performance of models trained on *ForNet* and on ImageNet. We adopt the training setup of (Nauen, Palacio, and Dengel 2025) and (Touvron, Cord, and Jégou 2022) for training ViT (Dosovitskiy et al. 2021), Swin (Liu et al. 2021) and ResNet (He et al. 2016) models as well as the setup of DeiT (Touvron et al. 2021) for that model (details in the supplementary material). Notably, *ForNet* improves performance across all tested architectures, including the ResNet models, demonstrating benefits beyond Transformers. When training with DeiT’s data augmentation, we only observe benefits on ImageNet for the larger models. When using the other data augmentation, we observe improvements from 1.2 p.p. to 4.5 p.p. for Transformers with increasing gains for larger models. Notably, *ForNet*’s improvements counteract the drop in performance for increasing model sizes. When training on ImageNet, this drop is 3.8 p.p. (ViT-S to L), while for *ForNet* it is reduced to 1.6 p.p.

To assess the transferability of *ForNet*-trained models, we finetune models pretrained on ImageNet and *ForNet* on five

Model	Aircraft	Cars	Flowers	Food	Pets
ViT-S @ ImageNet	72.4 ± 1.0	89.8 ± 0.3	94.5 ± 0.2	89.1 ± 0.1	93.8 ± 0.2
ViT-S @ <i>ForNet</i>	78.6 ± 0.5	92.2 ± 0.2	95.5 ± 0.2	89.6 ± 0.1	94.5 ± 0.2
	+6.2	+2.4	+1.0	+0.5	+0.7
ViT-B @ ImageNet	71.7 ± 0.5	90.0 ± 0.2	94.8 ± 0.4	89.8 ± 0.2	94.1 ± 0.4
ViT-B @ <i>ForNet</i>	79.0 ± 2.2	93.3 ± 0.1	96.5 ± 0.1	90.9 ± 0.1	95.1 ± 0.4
	+7.3	+3.3	+1.7	+1.1	+1.0
ViT-L @ ImageNet	72.1 ± 1.0	88.8 ± 0.3	94.4 ± 0.3	90.1 ± 0.2	94.2 ± 0.4
ViT-L @ <i>ForNet</i>	77.6 ± 1.2	89.1 ± 0.2	96.6 ± 0.1	91.3 ± 0.1	95.1 ± 0.1
	+5.5	+0.3	+2.2	+1.2	+0.9
DeiT-S @ ImageNet	75.3 ± 0.4	91.1 ± 0.2	94.8 ± 0.4	89.2 ± 0.2	92.4 ± 0.2
DeiT-S @ <i>ForNet</i>	76.8 ± 0.8	91.9 ± 0.2	95.2 ± 0.3	89.1 ± 0.2	92.3 ± 0.4
	+1.5	+0.8	+0.4	-0.1	-0.1
DeiT-B @ ImageNet	77.0 ± 1.2	92.9 ± 0.2	96.1 ± 0.2	91.2 ± 0.1	93.3 ± 0.4
DeiT-B @ <i>ForNet</i>	79.3 ± 0.3	93.1 ± 0.1	96.4 ± 0.2	91.3 ± 0.1	93.3 ± 0.1
	+2.3	+0.2	+0.3	+0.1	±0.0
DeiT-L @ ImageNet	72.8 ± 5.5	92.8 ± 1.0	95.8 ± 1.5	90.5 ± 2.6	92.4 ± 2.0
DeiT-L @ <i>ForNet</i>	78.8 ± 0.8	93.8 ± 0.2	97.0 ± 0.2	92.0 ± 0.2	93.5 ± 0.2
	+6.0	+1.0	+1.2	+1.5	+1.1
Swin-Ti @ ImageNet	77.0 ± 0.1	91.3 ± 0.6	95.9 ± 0.1	90.0 ± 0.2	94.2 ± 0.1
Swin-Ti @ <i>ForNet</i>	81.1 ± 0.8	92.8 ± 0.4	96.2 ± 0.1	90.4 ± 0.3	94.8 ± 0.5
	+4.1	+2.5	+0.3	+0.4	+0.6
Swin-S @ ImageNet	75.7 ± 1.4	91.0 ± 0.3	95.9 ± 0.5	91.1 ± 0.2	94.4 ± 0.1
Swin-S @ <i>ForNet</i>	81.4 ± 0.2	93.1 ± 0.2	96.3 ± 0.3	91.2 ± 0.2	94.9 ± 0.3
	+5.7	+2.1	+1.4	+0.1	+0.5
ResNet-50 @ ImageNet	78.2 ± 0.5	89.8 ± 0.2	91.7 ± 0.4	84.4 ± 0.2	93.7 ± 0.3
ResNet-50 @ <i>ForNet</i>	80.3 ± 0.4	90.4 ± 0.2	91.7 ± 0.2	84.5 ± 0.2	93.7 ± 0.3
	+2.1	+0.6	±0.0	+0.1	±0.0
ResNet-101 @ ImageNet	78.4 ± 0.6	90.3 ± 0.1	91.2 ± 0.5	86.0 ± 0.2	94.3 ± 0.2
ResNet-101 @ <i>ForNet</i>	81.4 ± 0.5	91.3 ± 0.1	92.9 ± 0.2	86.3 ± 0.1	94.0 ± 0.3
	+3.0	+1.3	+1.7	+0.3	-0.3

Table 6: Downstream accuracy in percent when finetuning on other datasets. Models were pretrained on *ForNet* and ImageNet. Pretraining on *ForNet* increases Transformer downstream accuracy on all datasets.

fine-grained datasets: FGVC-Aircraft (Maji et al. 2013), Stanford Cars (Dehghan et al. 2017), Oxford Flowers (Nilsback and Zisserman 2008), Food-101 (Kaur, Sikka, and Divakaran 2017), and Oxford-IIIT Pets (Parkhi et al. 2012). For Transformers, we see the accuracy improve on all downstream dataset by up to 7.3 p.p. Notably, training with *ForNet* increases the downstream performance of DeiT-S and DeiT-B, even though the ImageNet results were the same. These results demonstrate that the improved representations from training on *ForNet* translate to superior performance beyond gains from better ImageNet performance.

### 4.3 Bias and Robustness Evaluation

Beyond its use for training, *ForNet*'s unique properties and controlled data generation capabilities make it a powerful tool for analyzing behavior and biases of black-box models.

**Background Robustness** We assess the robustness of models to shifts in the background distribution from a class-related background to any background. Figure 3 presents the background robustness results for three datasets: *ForNet* (all backgrounds vs. backgrounds of same class), ImageNet9 (Xiao et al. 2020) (random backgrounds vs. original backgrounds), and CounterAnimal (Wang et al. 2024) (counter vs. common background). The top triangle of each arrow represents the in-distribution backgrounds and the bottom triangle represents the out-of-distribution ones. We follow ImageNet9 and CounterAnimal and assess the background robustness in terms of the accuracy gap when evaluating a model on images of normal background distribution compared to out-

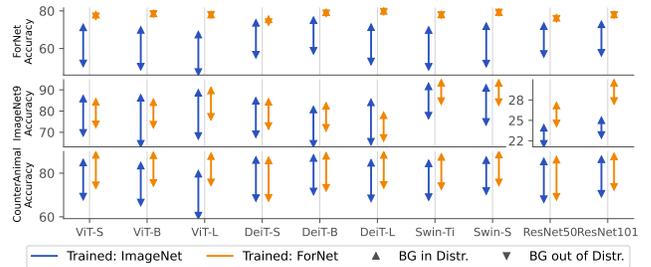


Figure 3: Evaluation of the background robustness on *ForNet*, ImageNet9 and CounterAnimal of models trained on *ForNet* and on ImageNet. Training on *ForNet* improves the background robustness of all models, reducing the background distribution-gap (arrow length).

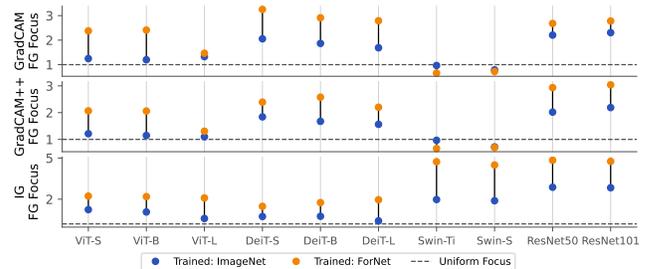


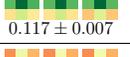
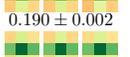
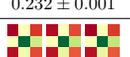
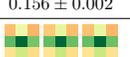
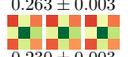
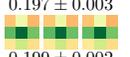
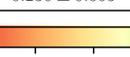
Figure 4: Evaluation of the foreground focus using GradCam, GradCam++ and IntegratedGradients (IG) of models trained on *ForNet* and on ImageNet. Training on *ForNet* improves the foreground focus of almost all models.

of-distribution backgrounds (length of each arrow). Crucially, training on *ForNet* instead of ImageNet improves the background robustness of all models, reducing the background-gap by boosting the performance on the out-of-background-distribution samples more than the in-distribution ones. These findings highlight the generalization benefits of *ForNet*.

**Foreground Focus** Leveraging our inherent knowledge of the foreground masks when using *ForNet*, as well as common XAI techniques (Selvaraju et al. 2016; Chattopadhyay et al. 2018; Sundararajan, Taly, and Yan 2017), we can evaluate a model's focus on the foreground object. We can directly evaluate ImageNet-trained models, but this technique can also be extended to other datasets without relying on manually annotated foreground-masks. To evaluate the foreground focus, we employ Grad-CAM (Selvaraju et al. 2016), GradCAM++ (Chattopadhyay et al. 2018) and IntegratedGradients (IG) (Sundararajan, Taly, and Yan 2017) to compute the per-pixel importance of an image for the model's prediction. The foreground focus is defined to be the ratio of the foreground's relative importance to its relative size in the image:

$$\text{FG Focus}(\text{img}) = \frac{\text{Area}(\text{img}) \text{ Importance}(\text{fg})}{\text{Area}(\text{fg}) \text{ Importance}(\text{img})} \quad (2)$$

If all pixels uniformly receive the same importance value, the foreground focus is one. The foreground focus of a model

Model	Center Bias when trained on		Delta
	ImageNet	<i>ForNet</i>	
ViT-S	 0.255 ± 0.008	 0.220 ± 0.003	-0.035
ViT-B	 0.254 ± 0.004	 0.190 ± 0.002	-0.064
ViT-L	 0.243 ± 0.011	 0.117 ± 0.007	-0.126
DeiT-S	 0.204 ± 0.002	 0.212 ± 0.001	+0.008
DeiT-B	 0.190 ± 0.007	 0.190 ± 0.002	±0.000
DeiT-L	 0.212 ± 0.002	 0.180 ± 0.002	-0.032
Swin-Ti	 0.250 ± 0.007	 0.165 ± 0.002	-0.085
Swin-S	 0.232 ± 0.001	 0.156 ± 0.002	-0.076
ResNet50	 0.263 ± 0.003	 0.197 ± 0.003	-0.066
ResNet101	 0.230 ± 0.003	 0.199 ± 0.002	-0.031

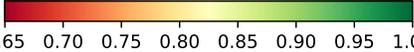


Table 7: We plot accuracy relative to the center accuracy of multiple instantiations of the models when the foreground objects is in different cells of a  $3 \times 3$  grid. Training on *ForNet* significantly reduces a models center bias.

is its average focus over all test images. Figure 4 presents our findings. Training on *ForNet* significantly increases the foreground focus of ViT/DeiT and ResNet across all metrics used. We hypothesize Swin’s below-uniform foreground focus with GradCam is due to its specific implementation.

**Center Bias** With *ForNet* we have unique control over the position of the foreground object in the image. This lets us quantify the center bias of ImageNet- and *ForNet*-trained models. We divide the image into a  $3 \times 3$  grid and evaluate model accuracy when the foreground object is in each of the 9 grid cells. Each cell’s accuracy is divided by the accuracy in the center cell for normalization, which gives us the relative performance drop when the foreground is in each part of the image. The center bias is calculated as one minus the average of the minimum performance of a corner cell and the minimum performance of a side cell:

$$\text{Center Bias} = 1 - \frac{\min_{c \in \text{sides}} \text{Acc}(c) + \min_{c \in \text{corners}} \text{Acc}(c)}{2\text{Acc}(c_{\text{center}})} \quad (3)$$

Table 7 visualizes the center bias of three instantiations of each model. Performance is generally highest in the center and lowest in the four corners. Interestingly, ImageNet-trained models perform slightly better when the foreground object is on the right side of the image, compared to the left side, despite our use of random flipping with a probability of 0.5 during training. Training on *ForNet* significantly reduces

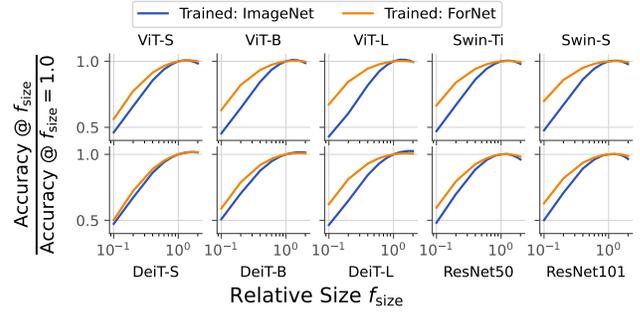


Figure 5: Evaluation of the size bias of models trained on ImageNet and *ForNet*. We plot the accuracy relative to the accuracy when using the default size ( $f_{\text{size}} = 1.0$ ).

center bias across models, with a more uniform performance especially across the middle row. This demonstrates that *ForNet* promotes a more uniform spatial attention distribution, counteracting the center-bias of ImageNet.

**Size Bias** Finally, we evaluate the impact of different sized foreground objects on the accuracy. For this evaluation, we use the *mean* foreground size strategy. We introduce a size factor  $f_{\text{size}}$  by which we additionally scale the foreground object before pasting it onto the background. Results are normalized by the accuracy when using  $f_{\text{size}} = 1.0$ . Figure 5 shows the size bias curves of models trained on ImageNet and *ForNet*. Models trained on *ForNet* maintain better performance even with smaller foreground objects, when ImageNet-trained models exhibit a more rapid performance decline. Therefore, *ForNet*-training improves robustness to variations in object scale, especially for larger models.

## 5 Discussion & Conclusion

We introduce *ForAug*, a novel data augmentation scheme that facilitates improved Transformer training for image classification. By explicitly separating and recombining foreground objects and backgrounds, *ForAug* enables controlled data augmentation beyond existing image compositions, leading to significant performance gains on ImageNet and downstream fine-grained classification tasks. Furthermore, *ForAug* provides a powerful framework for analyzing model behavior and quantifying biases, including background robustness, foreground focus, center bias, and size bias. Our experiments demonstrate that training on *ForNet*, the instantiation of *ForAug* on ImageNet, not only boosts accuracy but also significantly reduces these biases, resulting in more robust and generalizable models. In the future, we see *ForAug* be also applied to other datasets and tasks, like video recognition or segmentation. *ForAug*’s ability to both improve performance and provide insights into model behavior makes it a valuable tool for advancing CV research and developing more reliable AI systems.

## Acknowledgements

Will be in the final paper.

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- 2.5. Proof sketches or intuitions are given for complex and/or novel results (yes/partial/no) [Type your response here](#)
- 2.6. Appropriate citations to theoretical tools used are given (yes/partial/no) [Type your response here](#)
- 2.7. All theoretical claims are demonstrated empirically to hold (yes/partial/no/NA) [Type your response here](#)
- 2.8. All experimental code used to eliminate or disprove claims is included (yes/no/NA) [Type your response here](#)

### 3. Dataset Usage

- 3.1. Does this paper rely on one or more datasets? (yes/no) [yes](#)

If yes, please address the following points:

- 3.2. A motivation is given for why the experiments are conducted on the selected datasets (yes/partial/no/NA) [yes](#)
- 3.3. All novel datasets introduced in this paper are included in a data appendix (yes/partial/no/NA) [no](#)
- 3.4. All novel datasets introduced in this paper will be made publicly available upon publication of the paper with a license that allows free usage for research purposes (yes/partial/no/NA) [yes](#)
- 3.5. All datasets drawn from the existing literature (potentially including authors' own previously published work) are accompanied by appropriate citations (yes/no/NA) [yes](#)
- 3.6. All datasets drawn from the existing literature (potentially including authors' own previously published work) are publicly available (yes/partial/no/NA) [yes](#)
- 3.7. All datasets that are not publicly available are described in detail, with explanation why publicly available alternatives are not scientifically satisfying (yes/partial/no/NA) [NA](#)

### 4. Computational Experiments

- 4.1. Does this paper include computational experiments? (yes/no) [yes](#)

If yes, please address the following points:

- 4.2. This paper states the number and range of values tried per (hyper-) parameter during development of the paper, along with the criterion used for selecting the final parameter setting (yes/partial/no/NA) [yes](#)
- 4.3. Any code required for pre-processing data is included

in the appendix (yes/partial/no) [yes](#)

- 4.4. All source code required for conducting and analyzing the experiments is included in a code appendix (yes/partial/no) [yes](#)
- 4.5. All source code required for conducting and analyzing the experiments will be made publicly available upon publication of the paper with a license that allows free usage for research purposes (yes/partial/no) [yes](#)
- 4.6. All source code implementing new methods have comments detailing the implementation, with references to the paper where each step comes from (yes/partial/no) [yes](#)
- 4.7. If an algorithm depends on randomness, then the method used for setting seeds is described in a way sufficient to allow replication of results (yes/partial/no/NA) [yes](#)
- 4.8. This paper specifies the computing infrastructure used for running experiments (hardware and software), including GPU/CPU models; amount of memory; operating system; names and versions of relevant software libraries and frameworks (yes/partial/no) [yes](#)
- 4.9. This paper formally describes evaluation metrics used and explains the motivation for choosing these metrics (yes/partial/no) [yes](#)
- 4.10. This paper states the number of algorithm runs used to compute each reported result (yes/no) [yes](#)
- 4.11. Analysis of experiments goes beyond single-dimensional summaries of performance (e.g., average; median) to include measures of variation, confidence, or other distributional information (yes/no) [yes](#)
- 4.12. The significance of any improvement or decrease in performance is judged using appropriate statistical tests (e.g., Wilcoxon signed-rank) (yes/partial/no) [no](#)
- 4.13. This paper lists all final (hyper-)parameters used for each model/algorithm in the paper's experiments (yes/partial/no/NA) [yes](#)