Make ViT Faster with Multi-Exit Architecture

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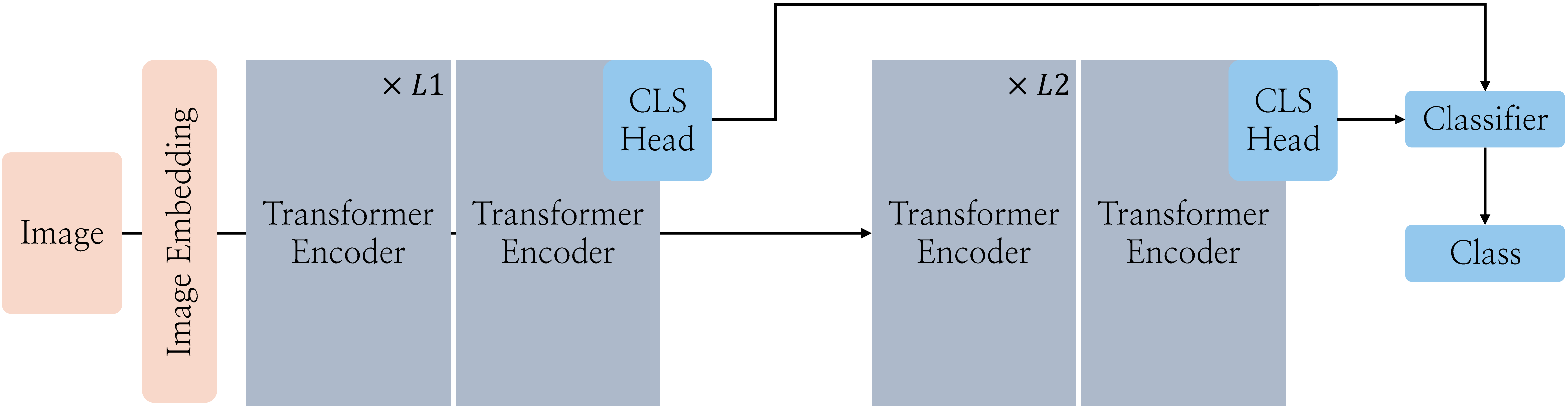
Motivation

- Despite achieving impressive performance, ViT faces challenges in inference due to its computationally expensive structure.
- While this may not be a significant concern for devices equipped with high computational power during inference, it becomes a critical issue when dealing with edge devices.

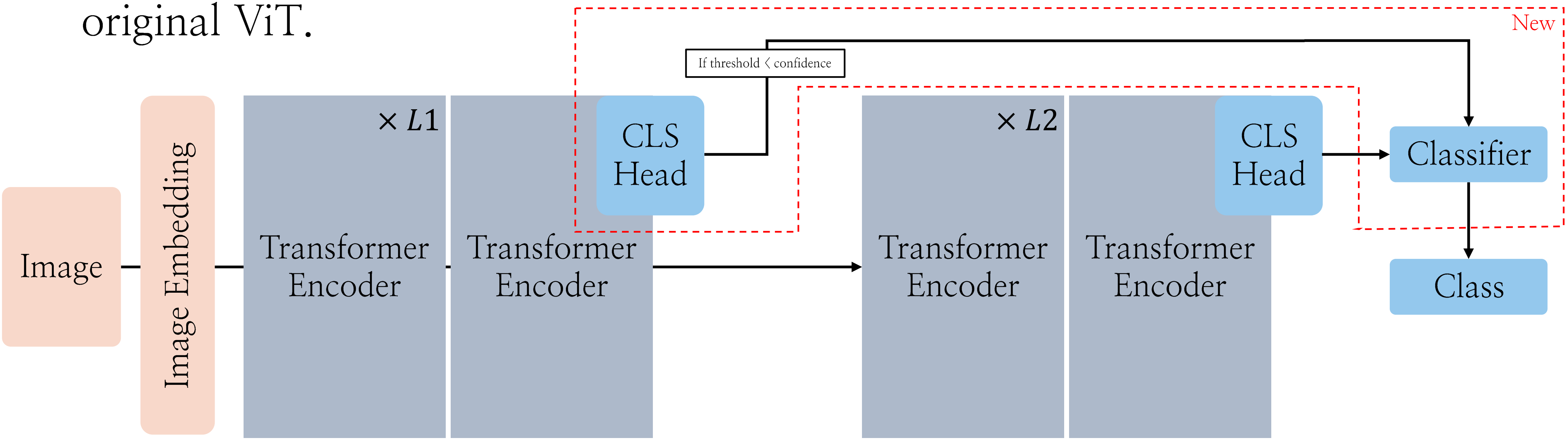
Goal

- Improve the inference speed of the Vision Transformer by utilizing a Multi-Exit Architecture.



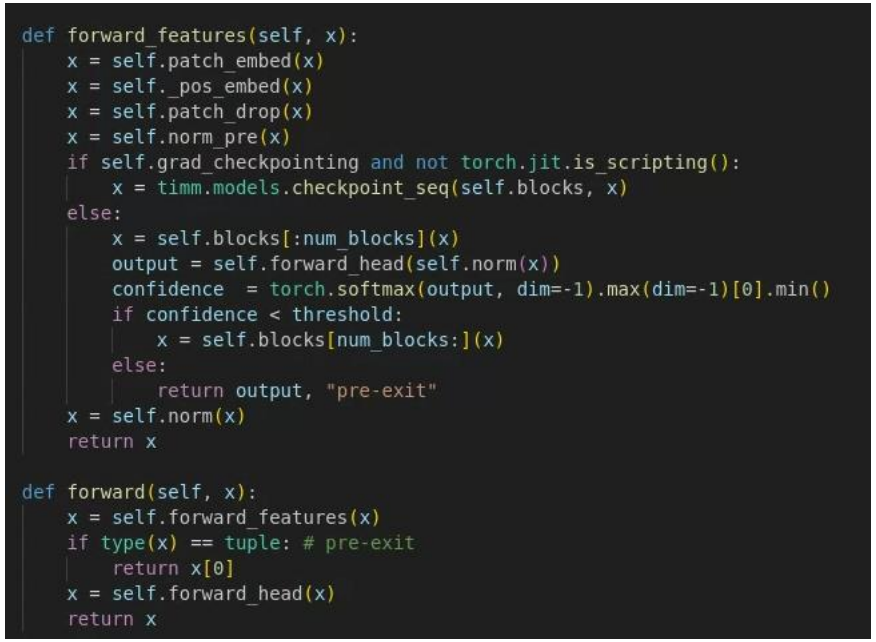
Architecture Details

- Residual connection is added between the intermediate transformer block and the classifier, while keeping the rest of the architecture the same as the original ViT.



Architecture Details

- if the new residual connection produces a highly confident output, it is immediately returned as the final result without proceeding further in the inference path. This approach speeds up the inference process by classifying more images through the residual path.



```python
def forward_features(self, x):
    x = self.patch_embed(x)
    x = self._pos_embed(x)
    x = self.patch_drop(x)
    x = self.norm_pre(x)
    if self.grad_checkpointing and not torch.jit.is_scripting():
        x = timm.models.checkpoint_seq(self.blocks, x)
    else:
        x = self.blocks[:num_blocks](x)
        output = self.forward_head(self.norm(x))
        confidence  = torch.softmax(output, dim=-1).max(dim=-1)[0].min()
        if confidence < threshold:
            x = self.blocks[num_blocks:](x)
        else:
            return output, "pre-exit"
    x = self.norm(x)
    return x

def forward(self, x):
    x = self.forward_features(x)
    if type(x) == tuple: # pre-exit
        return x[0]
    x = self.forward_head(x)
    return x
```

Experiment Setting, Dataset

- Imagenet-1k
- Since the majority of off-the-shelf pretrained ViT models are trained on the ImageNet-1k dataset, I have also utilized the ImageNet-1k dataset in my implementation.
- To expedite the training process, a subset of 50,000 images from the ImageNet-1k dataset was used for training, with an additional 10,000 images allocated for validation.

Experiment Setting, Others

- Pretrained Model：vit_base_patch16_224 (from huggingface timm repository)
- Position of Residual Path：3, 6, 9
- Classifier：Train from scratch / Fine tune / Doesn't Train
- Evalutation Metric：accuracy / inference speed (im/s)
- Threshold：0.01

Experiment Result,
Inference Speed Improvement

- Objective of this Experiment：In this experiment, to assess the maximum speed improvement, I have modified the setting so that all images will be outputted at the residual connection.
- Input Data：Random Value
- Device：RTX A6000

	Original Model	Residual Path at 9rd block	Residual Path at 6th block	Residual Path at 3th block
Inference Speed(im/s)	447.10	588.89	875.14	1714.03
Speed Improvement	1.00	1.32	1.96	3.83

Experiment Result,
Actual Inference Speed Improvement

- Objective of this Experiment: To evaluate the actual improvement in inference speed and potential accuracy drops
- Input Data: Imagenet-1k 10,000 images
- Device: RTX A6000

Classifier	Metric	Original Model	Residual Path at 3rd block	Residual Path at 6th block	Residual Path at 9th block
Same	Inference Speed(im/s)	439.84	438.82	439.74	440.39
	Speed Improvement	1.00	1.00	1.00	1.00
	Accuracy(%)	85.11	85.11	85.11	85.11
	Accuracy drop	0	0	0	0
Fine-Tune	Inference Speed(im/s)	440.88	440.44	440.04	440.43
	Speed Improvement	1.00	1.00	1.00	1.00
	Accuracy(%)	83.52	83.52	83.52	83.52
	Accuracy drop	0	0	0	0
Scratch	Inference Speed(im/s)	441.62	440.54	440.64	440.83
	Speed Improvement	1.00	1.00	1.00	1.00
	Accuracy(%)	81.02	80.92	80.91	80.97
	Accuracy drop	0.01	0.01	0.01	0.01

Experiment Result, CPU vs GPU

- Objective of this Experiment： Compare the performance on CPU and GPU

Data	Classifier	Device	Metric	Original Model	Residual Path at 3rd block	Residual Path at 6th block	Residual Path at 9th block
Imagenet-1k	Same	CPU	Inference Speed(im/s)	33.04	33.67	33.85	33.83
	Fine-Tune	CPU	Inference Speed(im/s)	28.51	28.92	32.39	31.41
			Speed Improvement	1.00	1.01	1.14	1.10
			Accuracy(%)	83.52	83.52	83.52	83.52
			Accuracy drop	0	0	0	0
		GPU	Inference Speed(im/s)	440.88	440.44	440.04	440.43
			Speed Improvement	1.00	1.00	1.00	1.00
			Accuracy(%)	83.52	83.52	83.52	83.52
			Accuracy drop	0	0	0	0
	Scratch	CPU	Inference Speed(im/s)	30.87	31.51	30.80	29.20

Conclusion

- This project focuses on implementing the multi-exit architecture on ViT and conducting various experiments to confirm its effectiveness.
- Although most of the experiments did not yield noticeable speed improvements, there were a few cases where slight improvements were observed.
- However, these improvements were not significant, indicating the need for further modifications to the architecture or exploration of alternative methods.

Appendix

Data	Classifier	Device	Metric	Original Model	Residual Path at 3rd block	Residual Path at 6th block	Residual Path at 9th block
Imagenet-1k	Same	CPU	Inference Speed(im/s)	33.04	33.67	33.85	33.83
			Speed Improvement	1.00	1.02	1.02	1.02
			Accuracy(%)	85.11	85.11	85.11	85.11
			Accuracy drop	0	0	0	0
		GPU	Inference Speed(im/s)	439.84	438.82	439.74	440.39
			Speed Improvement	1.00	1.00	1.00	1.00
			Accuracy(%)	85.11	85.11	85.11	85.11
			Accuracy drop	0	0	0	0
	Fine-Tune	CPU	Inference Speed(im/s)	28.51	28.92	32.39	31.41
			Speed Improvement	1.00	1.01	1.14	1.10
			Accuracy(%)	83.52	83.52	83.52	83.52
			Accuracy drop	0	0	0	0
		GPU	Inference Speed(im/s)	440.88	440.44	440.04	440.43
			Speed Improvement	1.00	1.00	1.00	1.00
			Accuracy(%)	83.52	83.52	83.52	83.52
			Accuracy drop	0	0	0	0
	Scratch	CPU	Inference Speed(im/s)	30.87	31.51	30.80	29.20
			Speed Improvement	1.00	1.02	1.00	0.95
			Accuracy(%)	81.02	80.92	80.91	80.97
			Accuracy drop	0.01	0.01	0.01	0.01
		GPU	Inference Speed(im/s)	441.62	440.54	440.64	440.83
			Speed Improvement	1.00	1.00	1.00	1.00
			Accuracy(%)	81.02	80.92	80.91	80.97
			Accuracy drop	0.01	0.01	0.01	0.01
Random Values	Same	CPU	Inference Speed(im/s)	22.33	30.68	44.96	88.40
			Speed Improvement	1.00	1.37	2.01	3.96
		GPU	Inference Speed(im/s)	447.10	588.89	875.14	1714.03
			Speed Improvement	1.00	1.32	1.96	3.83