ELimNet: Elimination based Lightweight Neural Net with Pretrained Weights

#Computer_Vision
#Lightweight
#Finetuning

HappyFace

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ELimNet: Elimination based Lightweight Neural Network with Pretrained Weights

Why

- Pretraining empty models constructed with AutoML NAS with Optuna costs too much time.
- Empty model underperforms pretrained models in terms of classification performance.
- Pretrained models underperforms empty NAS models in terms of inference time and in #params.

What

- **Adapting optimizing method for pretrained transformers models: dropping top layers.**
- **Removing Convolutional Top Layers from Pretrained Models(EfficientNet B0, ResNet18)**
- **Lightweight models with less than 1 Million #params with pretrained weights are proven to be effective.**

How

- Fetch pretrained torchvision models.
- Remove convolutional layers that are close to the loss function.
- Resize fully connected layers according to the remain top convolutional layer.
- Compare performance between original pretrained models, NAS models based on loss, accuracy and f1 score.
- Measure inference CPU and CUDA time.

Table of Contents

Costs of Time

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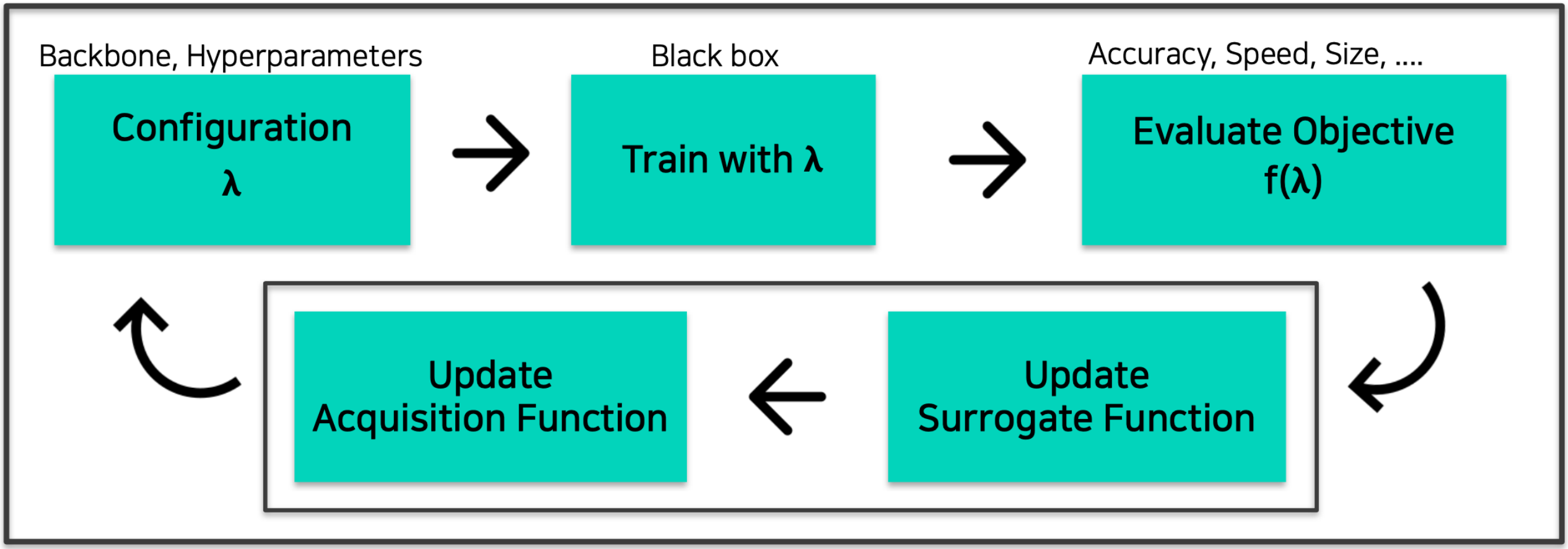

Bayesian Optimization is effective to search lightweight models, but costs too much time.

Costs of Time

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Input	Operator	t	c	n	s
$224^2 \times 3$	conv2d	-	32	1	2
$112^2 \times 32$	bottleneck	1	16	1	1
$112^2 \times 16$	bottleneck	6	24	2	2
$56^2 \times 24$	bottleneck	6	32	3	2
$28^2 \times 32$	bottleneck	6	64	4	2
$14^2 \times 64$	bottleneck	6	96	3	1
$14^2 \times 96$	bottleneck	6	160	3	2
$7^2 \times 160$	bottleneck	6	320	1	1
$7^2 \times 320$	conv2d 1x1	-	1280	1	1
$7^2 \times 1280$	avgpool 7x7	-	-	1	-
$1 \times 1 \times 1280$	conv2d 1x1	-	k	-	

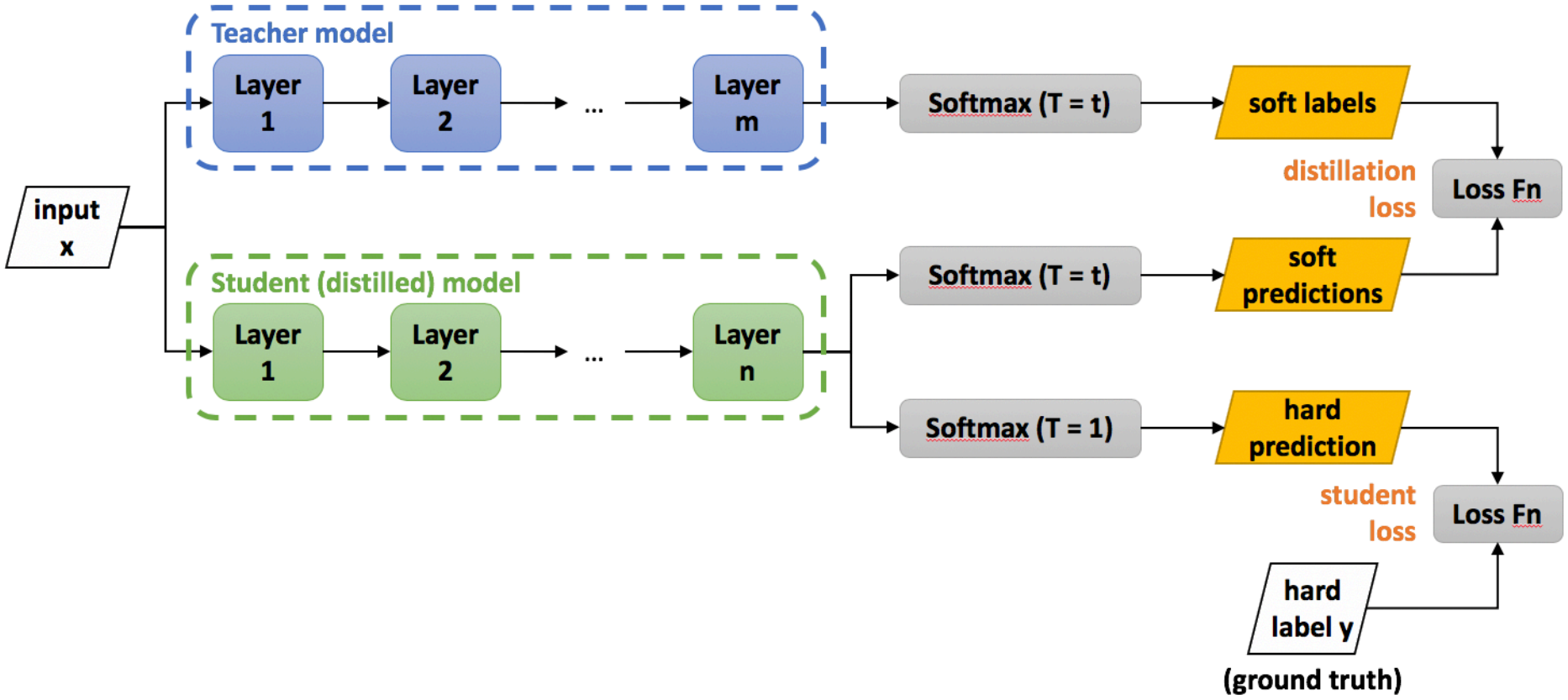
Mobilenetv2

```
BACKBONE:
  [
    # [repeat, module, args]
    [1, Conv, [32, 3, 2]],
    # InvertedResidualv2: [c, t, n, s]
    [1, InvertedResidualv2, [16, 1, 1]],
    [2, InvertedResidualv2, [24, 6, 2]],
    [3, InvertedResidualv2, [32, 6, 2]],
    [4, InvertedResidualv2, [64, 6, 2]],
    [3, InvertedResidualv2, [96, 6, 1]],
    [3, InvertedResidualv2, [160, 6, 2]],
    [1, InvertedResidualv2, [320, 6, 1]],
    [1, Conv, [1280, 1, 1]],
    [1, GlobalAvgPool, []],
    [1, Conv, [1000, 1, 1, null, 1, null]]
  ]
```

mobilenetv2.yaml

Even if the model is built, it is empty model without pretrained weights.

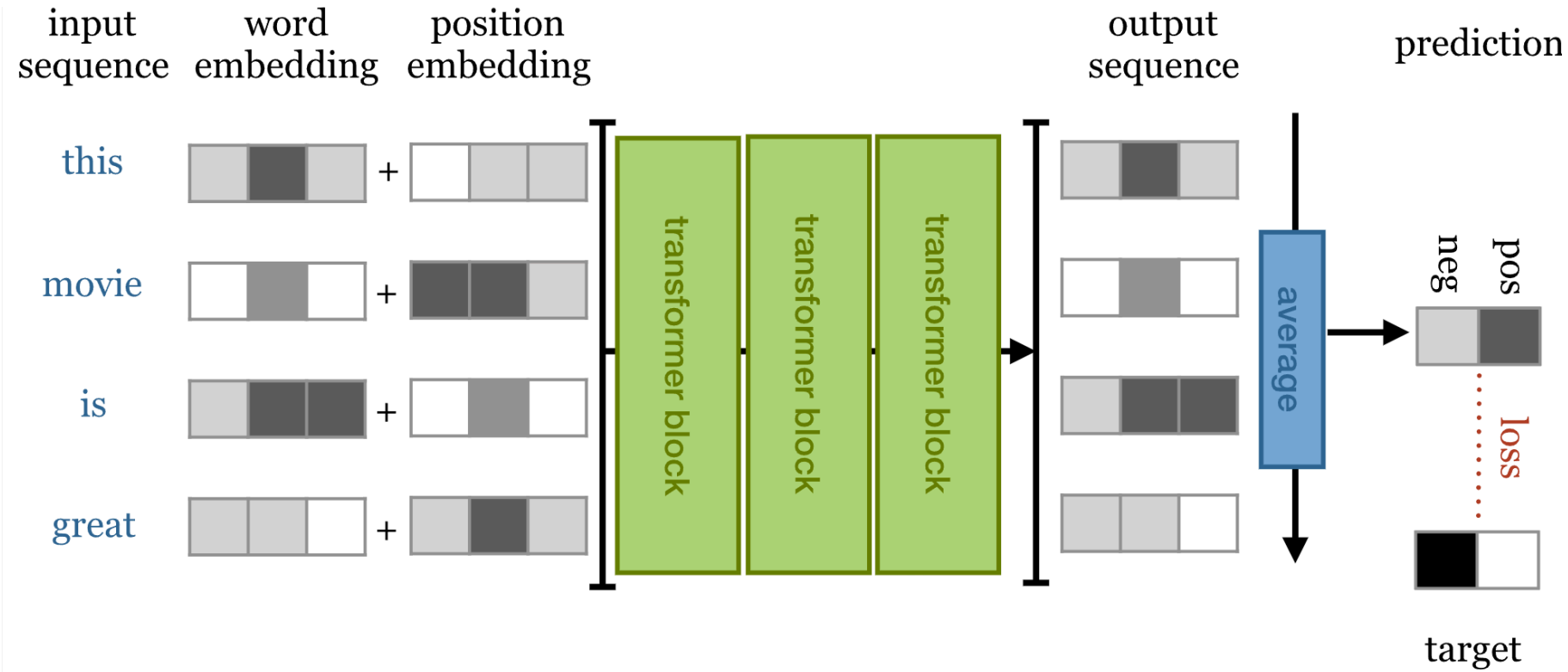
Costs of Time



Knowledge distillation from pretrained teacher model boosts performance but still requires 200+ epochs

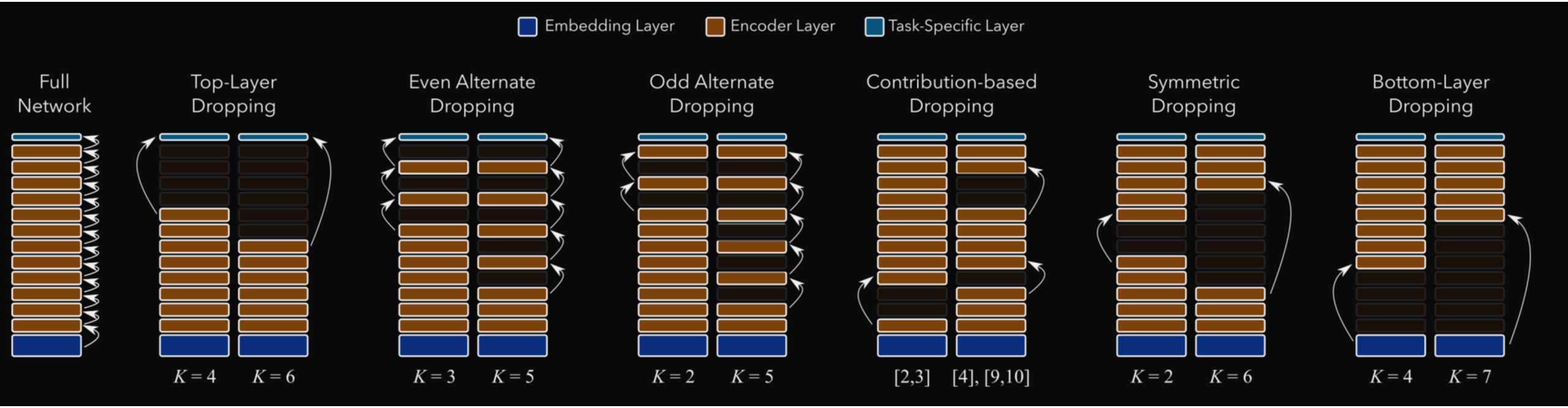
ELimNet Method

ELimNet Method



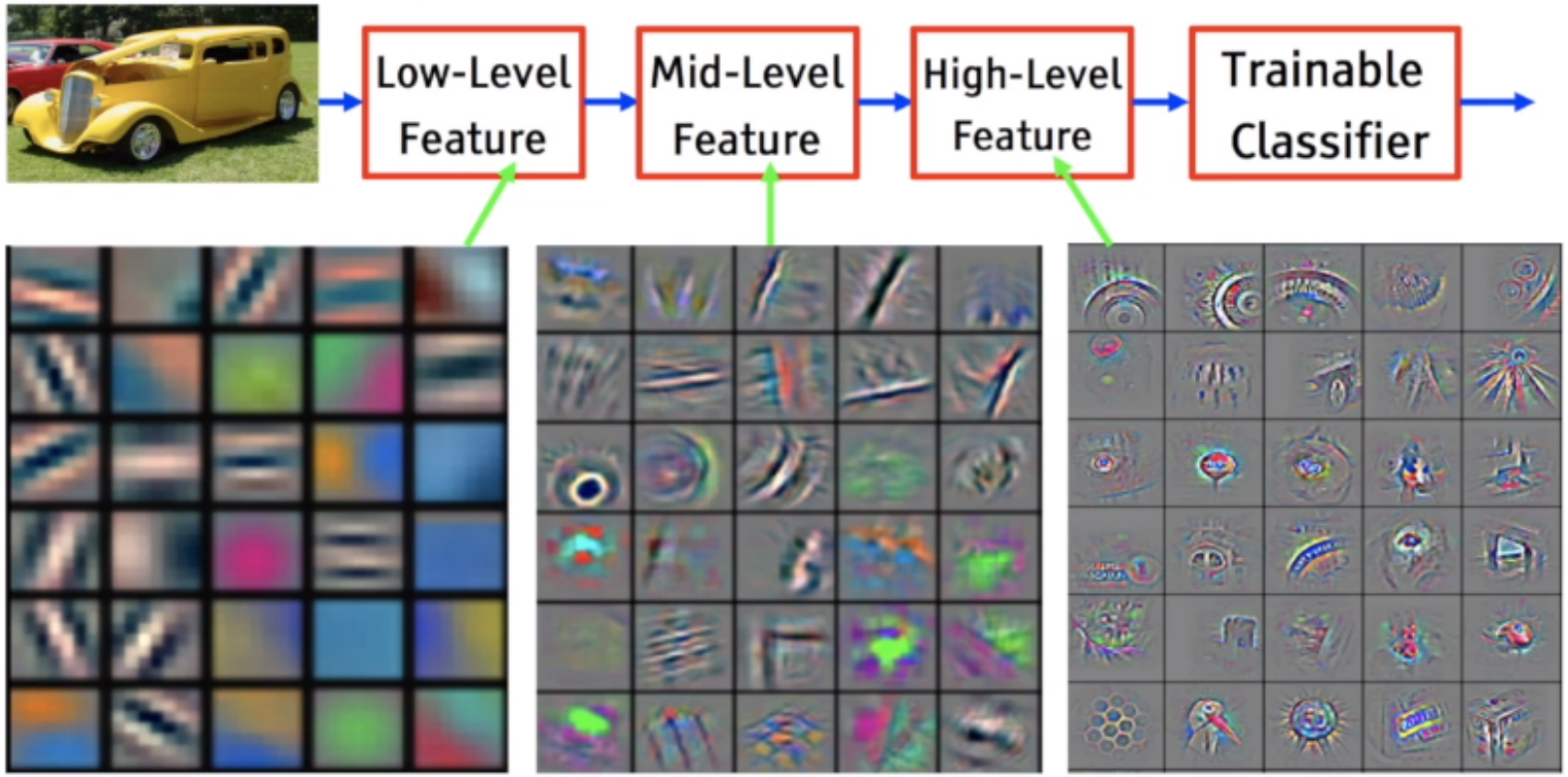
Transformers layers that are close to embeddings are embedding layers,
and layers that are close to the loss is task-specific layers.

ELimNet Method



Removing pretrained transformers top layers may yield 40% reduction in size, while preserving up to 98.2% of the performance.

ELimNet Method



Lower layers represent simple aspects of the image, Higher layers can represent sophisticated aspects.
Therefore, eliminated higher layers and used lower layers with pretrained weights for downstream task.

ELimNet Method

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Layer Name	Output Size	ResNet-18
conv1	$112 \times 112 \times 64$	7×7, 64, stride 2
conv2_x	$56 \times 56 \times 64$	3×3 max pool, stride 2
		$\begin{bmatrix} 3 \times 3, 64 \\ 3 \times 3, 64 \end{bmatrix} \times 2$
conv3_x	$28 \times 28 \times 128$	$\begin{bmatrix} 3 \times 3, 128 \\ 3 \times 3, 128 \end{bmatrix} \times 2$
conv4_x	$14 \times 14 \times 256$	$\begin{bmatrix} 3 \times 3, 256 \\ 3 \times 3, 256 \end{bmatrix} \times 2$
conv5_x	$7 \times 7 \times 512$	$\begin{bmatrix} 3 \times 3, 512 \\ 3 \times 3, 512 \end{bmatrix} \times 2$
average pool	$1 \times 1 \times 512$	7×7 average pool
fully connected	1000	512×1000 fully connections
softmax	1000	

Stage i	Operator $\hat{\mathcal{F}}_i$	Resolution $\hat{H}_i \times \hat{W}_i$
1	Conv3x3	224×224
2	MBConv1, k3x3	112×112
3	MBConv6, k3x3	112×112
4	MBConv6, k5x5	56×56
5	MBConv6, k3x3	28×28
6	MBConv6, k5x5	14×14
7	MBConv6, k5x5	14×14
8	MBConv6, k3x3	7×7
9	Conv1x1 & Pooling & FC	7×7

Selected ResNet18 and EfficientNet B0 as pretrained models.

ELimNet Method

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conv1	$112 \times 112 \times 64$	7×7, 64, stride 2
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9	Conv1x1 & Pooling & FC	7×7

Removing convolutional top layers from pretrained models for image classification task.

ELimNet Method

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softmax	1000	

```python
class ElimResNet18(nn.Module):
    def __init__(self):
        super(ElimResNet18, self).__init__()
        self.model = models.resnet18(pretrained=True)
        del self.model.layer3
        del self.model.layer4


        self.num_in_features = 128 # replace fully connected layers
        self.model.fc = nn.Linear(self.num_in_features, 6)

    def _forward_impl(self, x):
        x = self.model.conv1(x)
        x = self.model.bn1(x)
        x = self.model.relu(x)
        x = self.model.maxpool(x)

        x = self.model.layer1(x)
        x = self.model.layer2(x)
        # x = self.model.layer3(x)
        # x = self.model.layer4(x)

        x = self.model.avgpool(x)
        x = torch.flatten(x, 1)
        x = self.model.fc(x)
        return x

    def forward(self, x):
        return self._forward_impl(x)
```

Resizing fully connected layers accordingly

Performance of ELimNet

Pretrained Models vs ELimNet (Inference)

	# of Parameters	# of Layers	CPU times (sec)	CUDA time (sec)	Submitted Time
Pretrained EfficientNet B0	4.0M	352	3.9s	**4.0s**	105.6819
EfficientNet B0 Elim 2	0.9M	245	4.1s	13.0s	83.4161
EfficientNet B0 Elim 3	0.30M	181	**3.0s**	9.0s	**73.4604**
Resnet18	11.17M	69	-	-	-
Resnet18 Elim 2	0.68M	37	-	-	-

Construct lightweight CNN model with less than 1M #params, saves inference time by 20%.

Pretrained Models vs ELimNet (Train)

[100 epochs]	# of Parameters	# of Layers	Train	Validation	Submitted F1
Pretrained EfficientNet B0	4.0M	352	Loss: 0.43 Acc: 81.23 F1: 0.77	Loss: 0.469 Acc: 82.17 F1: 0.76	0.7493
EfficientNet B0 Elim 2	0.9M	245	loss:0.652, acc: 87.22%, **f1: 0.84**	Loss: 0.622, Acc: 80.14% **F1: 0.77**	**0.7603**
EfficientNet B0 Elim 3	**0.30M**	**181**	Loss: 0.602, Acc: 78.17% F1: 0.74	Loss: 0.661, Acc: 77.41% F1: 0.74	0.7349
Resnet18	11.17M	69	Loss: 0.578, Acc: 78.90% **F1: 0.76**	Loss: 0.700, Acc: 76.17% F1: 0.719	-
Resnet18 Elim 2	**0.68M**	**37**	**Loss: 0.447,** **Acc: 83.73%** F1: 0.71	Loss: 0.712, Acc: 75.42% F1: 0.71	-

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EfficientNet B0 Elim 3	0.30M	181	Loss: 0.618, Acc: 78.17% F1: 0.74	Loss: 0.661, Acc: 77.41% F1: 0.74	0.7348
Resnet18	11.17M	69	Loss: 0.578, Acc: 78.90% **F1: 0.76**	Loss: 0.700, Acc: 76.17% F1: 0.719	-
Resnet18 Elim 2	**0.68M**	**37**	**Loss: 0.447,** **Acc: 83.73%** F1: 0.71	Loss: 0.712, Acc: 75.42% F1: 0.71	-

Reduces parameters to 7%(or less)
of its original parameters while maintaining its performance.

NAS + HPO vs ELimNet (Inference)

	# of Parameters	# of Layers	CPU times (sec)	CUDA time (sec)	Submitted time
Empty MobileNet V3	4.2M	227	4	13	-
Empty EfficientNet B0	1.3M	352	3.780	3.782	68.3922
Empty DWConv & InvertedResidualv3 NAS	0.08M	66	**1**	**3.5**	61.1138
Empty MBConv NAS	0.33M	141	2.14	7.201	67.0518
EfficientNet B0 Removed 3	0.30M	181	3.0s	9s	73.4604
Resnet18 Removed 2	0.68M	37	-	-	-

Maintaining low layers' pretrained weights underperformed in inference time to NAS & HPO model searched with Optuna.

Empty NAS + HPO Models vs ELimNet (Train)

[100 epochs]	# of Parameters	# of Layers	Train	Valid	Submitted F1
Empty MobileNet V3	4.2M	227	Loss 0.925 Acc: 65.18 F1: 0.58	Loss 0.993 Acc: 62.83 F1: 0.56	-
Empty EfficientNet B0	1.3M	352	Loss 0.867 Acc: 67.28 F1: 0.61	Loss 0.898 Acc: 66.80 F1: 0.61	0.6337
Empty DWConv & InvertedResidualv3 NAS	**0.08M**	66	-	Loss: 0.766 Acc: 71.71 F1: 0.68	0.6740
Empty MBConv NAS	0.33M	141	Loss: 0.786 Acc: 70.72 F1: 0.66	Loss: 0.866 Acc: 68.09 F1: 0.62	0.6245
Resnet18 Removed 2	0.68M	37	**Loss: 0.447** **Acc: 83.73%** F1: 0.71	Loss: 0.712 Acc: 75.42% F1: 0.71	**0.7603**
EfficientNet B0 Removed 3	0.30M	181	Loss: 0.602 Acc: 78.17% **F1: 0.74**	Loss: 0.661 Acc: 77.41% **F1: 0.74**	0.7349

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Empty DWConv & InvertedResidualv3 NAS	**0.08M**	66	-	Loss: 0.766 Acc: 71. F1: 0.68	0.6740
Empty MBConv NAS	0.33M	141	Loss: 0.786 Acc: 70.72 F1: 0.66	Loss: 0.866 Acc: 68.09 F1: 0.62	0.6245
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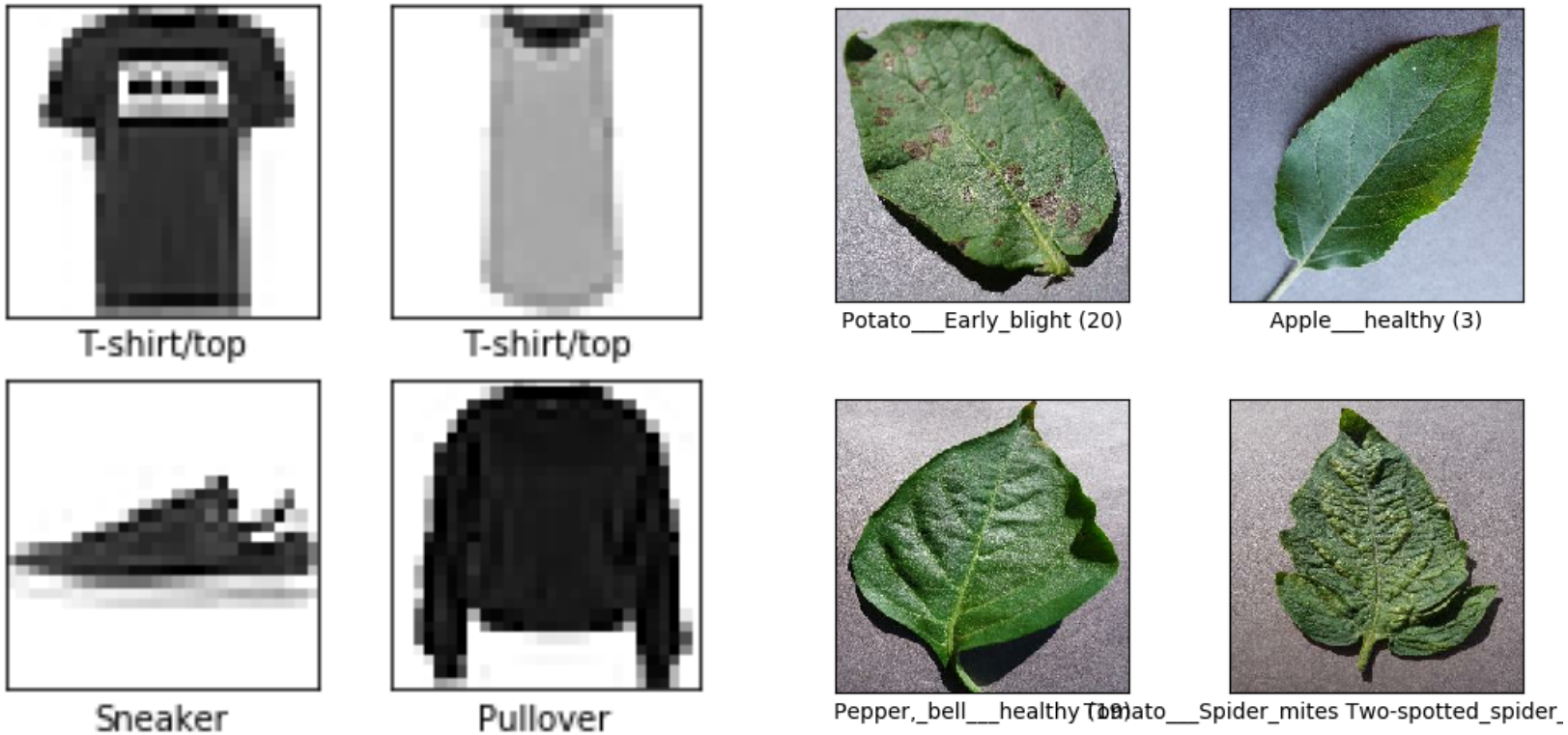
EfficientNet B0 Removed 3	0.30M	181	Loss: 0.602 Acc: 78.17% **F1: 0.74**	Loss: 0.661 Acc: 77.41% **F1: 0.74**	0.7349

Filled can is better than empty can.

Work in Progress

- Will add ResNet18's inference time data and compare with Optuna NAS constructed lightweight model.
- Will test on pretrained MobileNetV3, MnasNet on torchvision.
- Will be applied on other small datasets such as Fashion MNIST dataset and Plant Village dataset.

https://github.com/snoop2head/elimnet



End Remark

Steve Rogers : Big man in a suit of armour. Take that off, what are you?
Tony Stark : Genius, billionaire, playboy, philanthropist.

Thank you

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- Removing Convolutional Top Layers from Pretrained Models(EfficientNet B0, ResNet18)
- Lightweight models with less than 1 Million #params with pretrained weights are proven to be effective.

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- Fetch pretrained torchvision models.
- Remove convolutional layers that are close to the loss function.
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- Compare performance between original pretrained models, NAS models based on loss, accuracy and f1 score.
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Q&A