Active Convolution: Learning the Shape of Convolution for Image Classification

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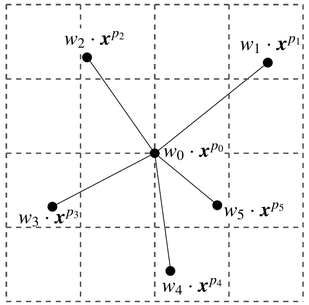
Motivation

- The shape of convolution is fixed and assigned by hand
- Depending on the applications, the receptive field can vary widely
- → How about to **learn the shape of convolution by network itself**?

Active Convolution Unit(ACU)

- Parametrize the position of inputs

$$\boldsymbol{Y} = \boldsymbol{W} * \boldsymbol{X}_{\theta_p} + \boldsymbol{b}$$



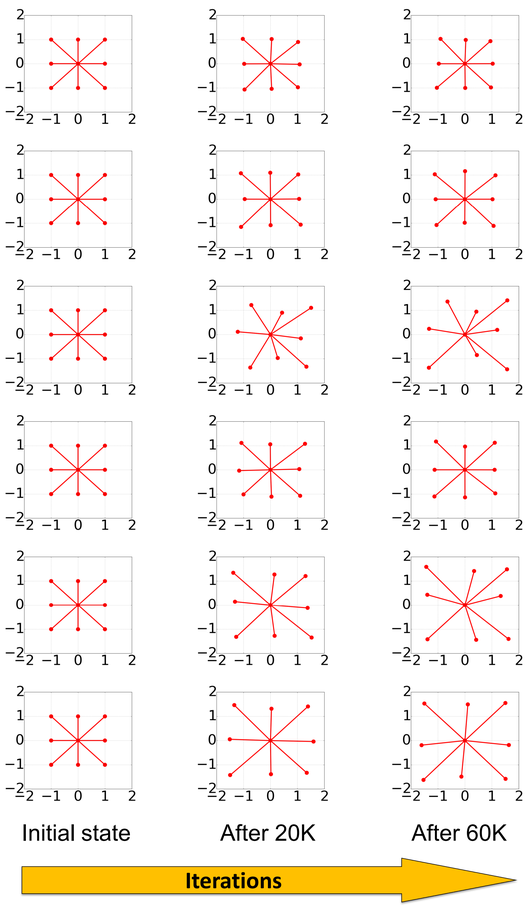
- θ_p : the displacement from the center
- Use bilinear interpolation
  → Outputs are differentiable by θ_p
- Normalized gradient
  - To control the movement of synapses stably, we used only the direction of the derivatives, and not the magnitude

$$Z = \sqrt{(\frac{\partial L}{\partial \alpha_k})^2 + (\frac{\partial L}{\partial \beta_k})^2} \qquad \overline{\frac{\partial L}{\partial \alpha_k}} = \frac{\partial L}{\partial \alpha_k}/Z, \ \overline{\frac{\partial L}{\partial \beta_k}} = \frac{\partial L}{\partial \beta_k}/Z$$

Advantages

- The shape of convolution can be learned by backpropagation
  - The network learns efficient shape according to its input
- Can define any shape of convolution
  - The shape does not need to be rectangular
- Got an improvement by changing conventional convolution to ACU
  - Only 8 more parameters per layer are needed for 3x3 convolution

Changes of the Convolution Shape



Experimental Results

- CIFAR10/100

Network		base	ACU	Improvement
Plain	CIFAR10	8.01	7.33	**+0.68**
	CIFAR100	27.85	27.11	**+0.74**
Residual	CIFAR10	7.64	7.12	**+0.52**
	CIFAR100	27.93	27.47	**+0.46**

- Place365

Network	base	ACU	Improvement
AlexNet	81.29	82.08	**+0.79**
ResNet26	85.24	85.73	**+0.49**

Ablation Study

Model	Description	improvement	# of params
Base	Basic plain network	-	0.82M
Base-D2	Apply dilation 2 to conv3/x layers	-0.02	
ACU-Round	Round trained positions and fine-tune 20k	+0.32	
ACU-C23	Use conventional conv for conv1/x layers	+0.58	
ACU-all	Use ACU for all 3x3 convs	**+0.68**	
Base-F5	Use 5x5 filter for conv3/x layers	+0.72	1.66M
ACU-F5	Use ACU on Base-F5(including 5x5 convs)	**+1.12**	

Code is available at https://github.com/jyh2986/Active-Convolution