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
  \[ Y = W \ast X \theta_p + b \]
- \( \theta_p \): the displacement from the center
- Use bilinear interpolation
- Outputs are differentiable by \( \theta_p \)
- Normalized gradient
  - To control the movement of synapses stably, we used only the direction of the derivatives, and not the magnitude
  \[ Z = \frac{1}{\sqrt{1 + (\frac{dL}{d\theta_1})^2 + (\frac{dL}{d\theta_2})^2}} \cdot \frac{dL}{d\theta_1} = \frac{dL}{d\theta_2} = \frac{dL}{d\theta_3} = \frac{dL}{d\theta_4} \]

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

Experimental Results

- CIFAR10/100
- Place365

Ablation Study

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

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