# MobileNet v1

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# Contents

- Backgrounds
- Relative Works
- Architecture
- Experiments & Results

# Backgrounds

About Network Compression

# Backgrounds

- Depth-wise separable convolutions.
- Use Inception models to reduce the computation in the first few layers.
- Compression based on product quantization, hashing, pruning, vector quantization, Huffman coding
- Various factorization
- Distillation which uses a larger network to teach a smaller network.

# Relative Works

Other Networks

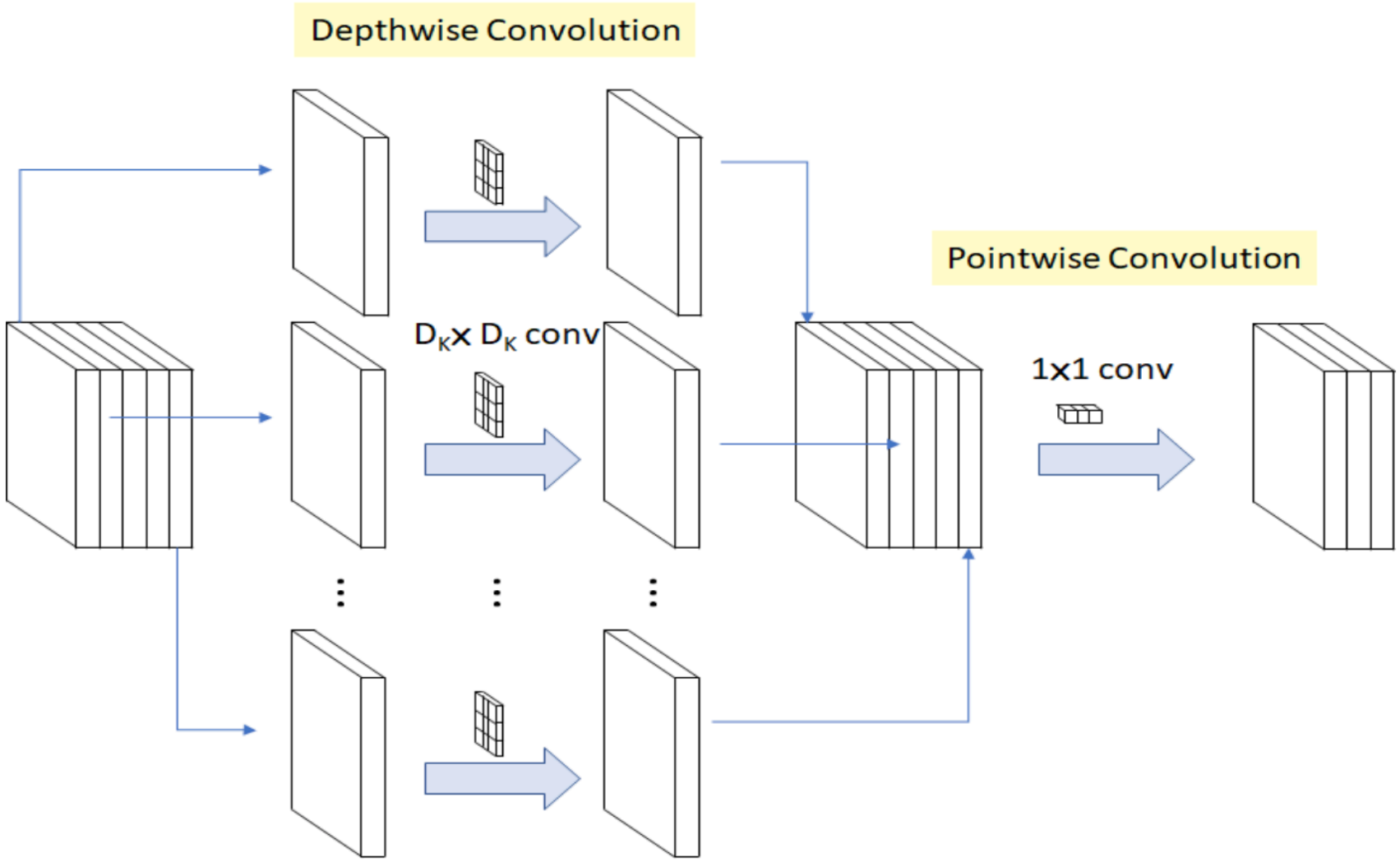
# Relative Works

- Xception network demonstrated how to scale up depthwise separable filters to outperform Inception V3 networks.
- Squeezenet which uses a bottleneck approach to design a very small network
- Structed transform networks, deep fried convnets reduced computation

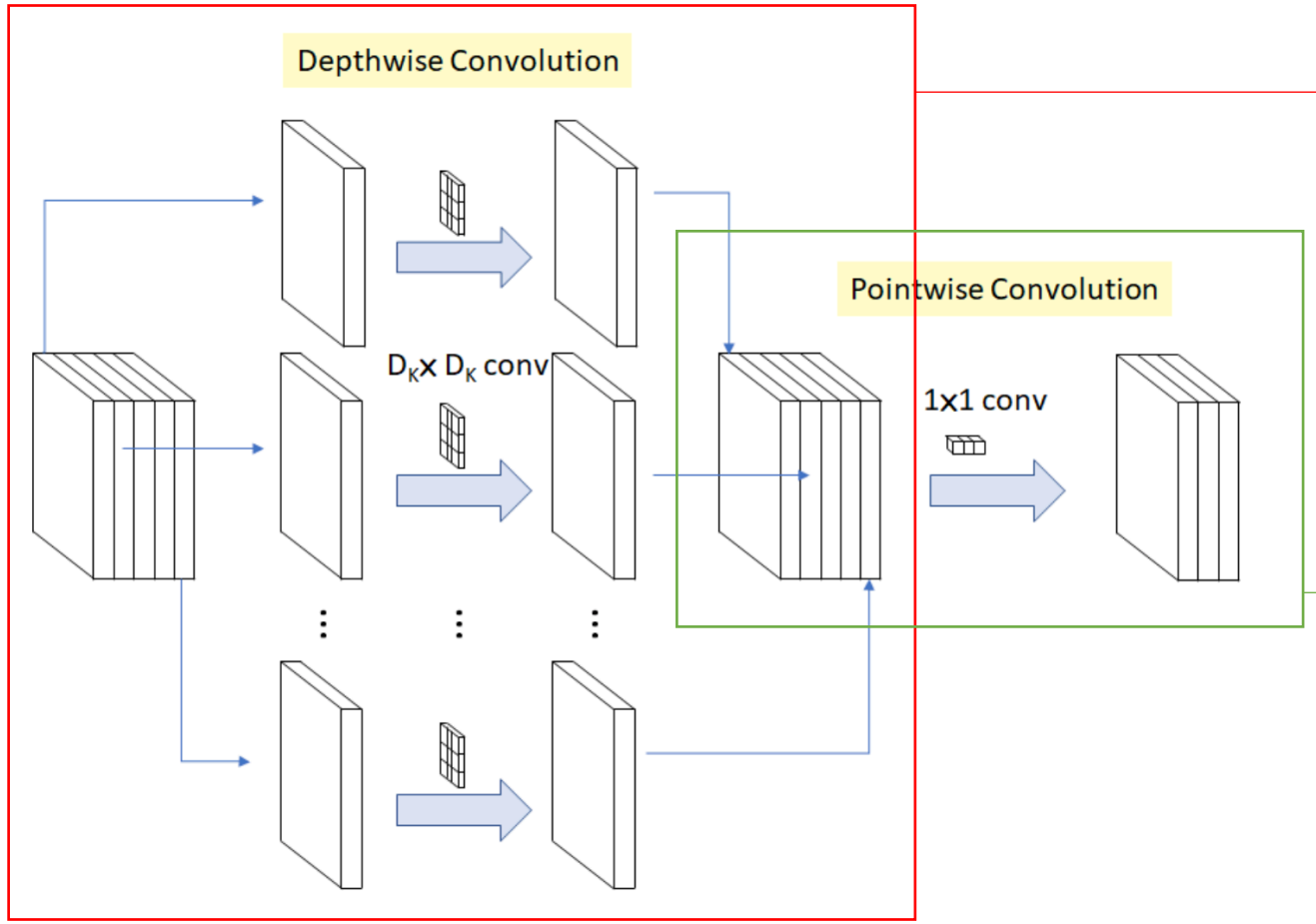
# Architecture

Depth-wise Separable Convolution / Network Architecture

# Depth-wise Separable Convolution



# Depth-wise Separable Convolution




$$D_K \cdot D_K \cdot M \cdot D_F \cdot D_F + M \cdot N \cdot D_F \cdot D_F$$

# Comparison

Depth-wise Separable Convolution : $D_K \cdot D_K \cdot M \cdot D_F \cdot D_F + M \cdot N \cdot D_F \cdot D_F$

Standard Convolution : $D_K \cdot D_K \cdot M \cdot N \cdot D_F \cdot D_F$

$$\frac{D_K \cdot D_K \cdot M \cdot D_F \cdot D_F + M \cdot N \cdot D_F \cdot D_F}{D_K \cdot D_K \cdot M \cdot N \cdot D_F \cdot D_F}$$

$$= \frac{1}{N} + \frac{1}{D_K^2}$$

When Filter-size is 3x3, 8 to 9 times less computation can be achieved, but with only small reduction in accuracy.

# Basic Block

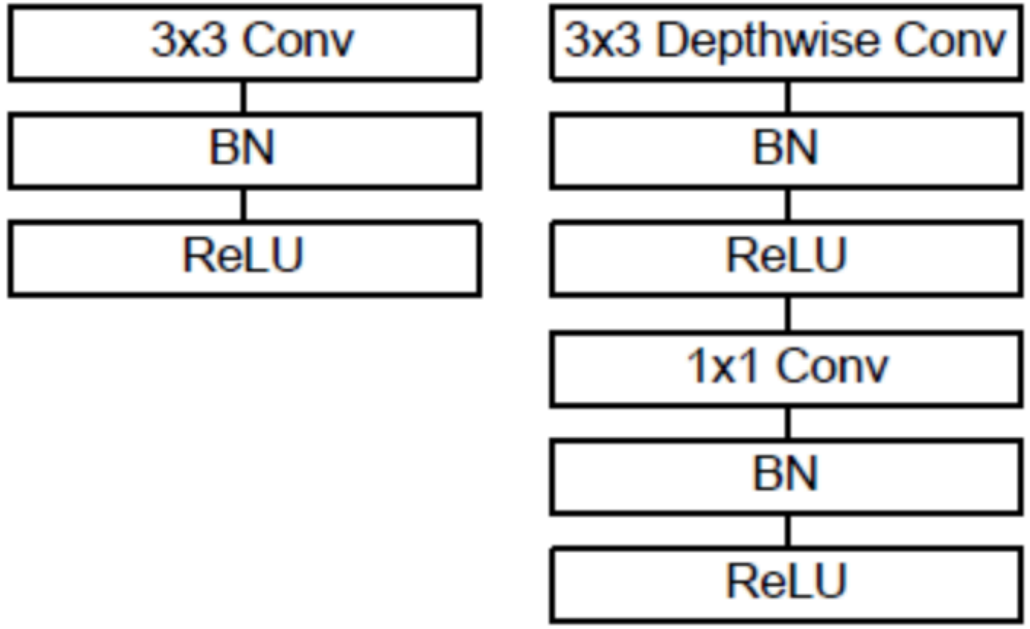



Table 4. Depthwise Separable vs Full Convolution MobileNet

| Model | ImageNet Accuracy | Million Mult-Adds | Million Parameters |
|---|---|---|---|
| Conv MobileNet | 71.7% | 4866 | 29.3 |
| MobileNet | 70.6% | 569 | 4.2 |

# Network Architecture

Table 1. MobileNet Body Architecture

| Type / Stride | Filter Shape | Input Size |
|---|---|---|
| Conv / s2 | $3 \times 3 \times 3 \times 32$ | $224 \times 224 \times 3$ |
| Conv dw / s1 | $3 \times 3 \times 32$ dw | $112 \times 112 \times 32$ |
| Conv / s1 | $1 \times 1 \times 32 \times 64$ | $112 \times 112 \times 32$ |
| Conv dw / s2 | $3 \times 3 \times 64$ dw | $112 \times 112 \times 64$ |
| Conv / s1 | $1 \times 1 \times 64 \times 128$ | $56 \times 56 \times 64$ |
| Conv dw / s1 | $3 \times 3 \times 128$ dw | $56 \times 56 \times 128$ |
| Conv / s1 | $1 \times 1 \times 128 \times 128$ | $56 \times 56 \times 128$ |
| Conv dw / s2 | $3 \times 3 \times 128$ dw | $56 \times 56 \times 128$ |
| Conv / s1 | $1 \times 1 \times 128 \times 256$ | $28 \times 28 \times 128$ |
| Conv dw / s1 | $3 \times 3 \times 256$ dw | $28 \times 28 \times 256$ |
| Conv / s1 | $1 \times 1 \times 256 \times 256$ | $28 \times 28 \times 256$ |
| Conv dw / s2 | $3 \times 3 \times 256$ dw | $28 \times 28 \times 256$ |
| Conv / s1 | $1 \times 1 \times 256 \times 512$ | $14 \times 14 \times 256$ |
| $5\times$ Conv dw / s1 | $3 \times 3 \times 512$ dw | $14 \times 14 \times 512$ |
| $5\times$ Conv / s1 | $1 \times 1 \times 512 \times 512$ | $14 \times 14 \times 512$ |
| Conv dw / s2 | $3 \times 3 \times 512$ dw | $14 \times 14 \times 512$ |
| Conv / s1 | $1 \times 1 \times 512 \times 1024$ | $7 \times 7 \times 512$ |
| Conv dw / s2 | $3 \times 3 \times 1024$ dw | $7 \times 7 \times 1024$ |
| Conv / s1 | $1 \times 1 \times 1024 \times 1024$ | $7 \times 7 \times 1024$ |
| Avg Pool / s1 | Pool $7 \times 7$ | $7 \times 7 \times 1024$ |
| FC / s1 | $1024 \times 1000$ | $1 \times 1 \times 1024$ |
| Softmax / s1 | Classifier | $1 \times 1 \times 1000$ |

Whole Network Architecture for MobileNet

# Width, Resolution Multiplier

$$D_K \cdot D_K \cdot \alpha M \cdot D_F \cdot D_F + \alpha M \cdot \alpha N \cdot D_F \cdot D_F$$

Table 6. MobileNet Width Multiplier

| Width Multiplier | ImageNet Accuracy | Million Mult-Adds | Million Parameters |
|---|---|---|---|
| 1.0 MobileNet-224 | 70.6% | 569 | 4.2 |
| 0.75 MobileNet-224 | 68.4% | 325 | 2.6 |
| 0.5 MobileNet-224 | 63.7% | 149 | 1.3 |
| 0.25 MobileNet-224 | 50.6% | 41 | 0.5 |

$$D_K \cdot D_K \cdot \alpha M \cdot \rho D_F \cdot \rho D_F + \alpha M \cdot \alpha N \cdot \rho D_F \cdot \rho D_F$$

Table 7. MobileNet Resolution

| Resolution | ImageNet Accuracy | Million Mult-Adds | Million Parameters |
|---|---|---|---|
| 1.0 MobileNet-224 | 70.6% | 569 | 4.2 |
| 1.0 MobileNet-192 | 69.1% | 418 | 4.2 |
| 1.0 MobileNet-160 | 67.2% | 290 | 4.2 |
| 1.0 MobileNet-128 | 64.4% | 186 | 4.2 |

# Experiments & Results

# Experiments & Results

Table 8. MobileNet Comparison to Popular Models

| Model | ImageNet Accuracy | Million Mult-Adds | Million Parameters |
|---|---|---|---|
| 1.0 MobileNet-224 | 70.6% | 569 | 4.2 |
| GoogleNet | 69.8% | 1550 | 6.8 |
| VGG 16 | 71.5% | 15300 | 138 |

Table 9. Smaller MobileNet Comparison to Popular Models

| Model | ImageNet Accuracy | Million Mult-Adds | Million Parameters |
|---|---|---|---|
| 0.50 MobileNet-160 | 60.2% | 76 | 1.32 |
| Squeezenet | 57.5% | 1700 | 1.25 |
| AlexNet | 57.2% | 720 | 60 |

# Thank You.