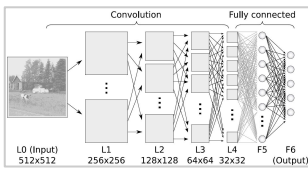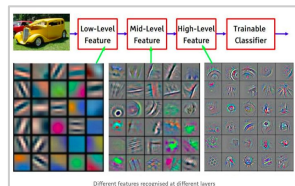## Convolution Operations

> Convolutions are a filter operations in Computer Vision
> Extracting useful information from images
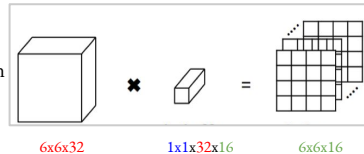> Sliding windows (kernels or filters) are used to convolve an input image



## Convolution in CNN Architectures

> Convolution: filtering
> Stride: sliding step size
> Padding: control output size
> Pooling: downsampling



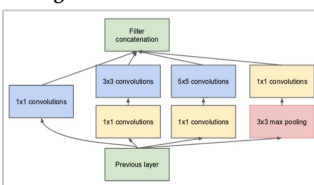## 1x1 conv

> Feature pooling
> Decreases parameters
> Decreases computation
> Adds nonlinearity



6x6x32          1x1x32x16          6x6x16
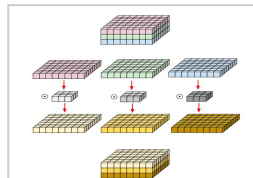
## Inception/GoogLeNet

> Uses bottleneck layer
> Decreases computation (10x)
> Auxiliary loss layers
> Factorizes bigger conv layers
> Regularization



## Depthwise Convolution

> Each kernel is kept separately
> Split input & kernels into channels
> Convolve each input channel with corresponding filter channel
> Stack the output (2D) tensors back together



## MobileNet

> Depthwise separable convolutions
> Shrinking hyperparameters
> Width multiplier: adjusts # of channels
> Resolution multiplier: adjusts input image and feature map resolutions



(b) Depthwise Convolutional Filters

(c) $1 \times 1$ Convolutional Filters called Pointwise Convolution in the context of Depthwise Separable Convolution
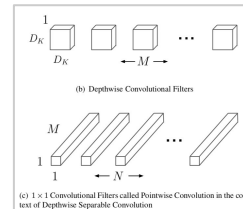
## Channel Shuffling-ShuffleNet

> Eliminates main **side effect** of grouped convs
> **Side effect:** outputs are derived only from certain channels, shuffles the channels after grouped convolutions
> Applies group convolutions also on 1x1 layers
> Note: channel shuffling is also differentiable!
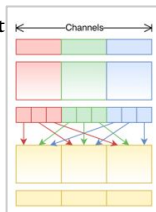


## 11x11 vs 3x3

> Bigger filters capture, more global information
> Smaller filters captures more local information
> AlexNet uses 11x11, 55x55 and 3x3
> VGGNet uses only 3x3 filters
> By VGGNet, effectivity of going deeper proved

Filter size: 3x3
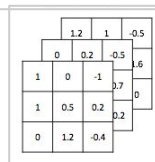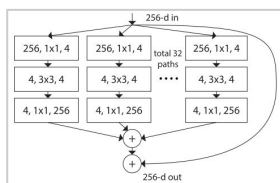


## Residual Nets

> Identity shortcut (residual) connections
> Helps for gradient flow
> Skipping one or more layers
> Deeper architectures work better
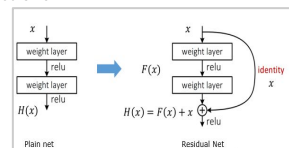


## ResNeXt

> Inception style in ResNet
> Depth concatenation, same convolution topology
> Having high cardinality helps in decreasing validation error
> New hyper-parameter : cardinality → width size



## DenseNet

> Connecting all layers to the other layers
> Strong gradient flow
> More diversified features
> Allowing feature re-use
> More memory-hungry,
> Computationally more efficient
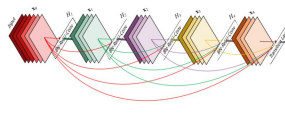


# Cheat Sheet
# Convolution Operations