

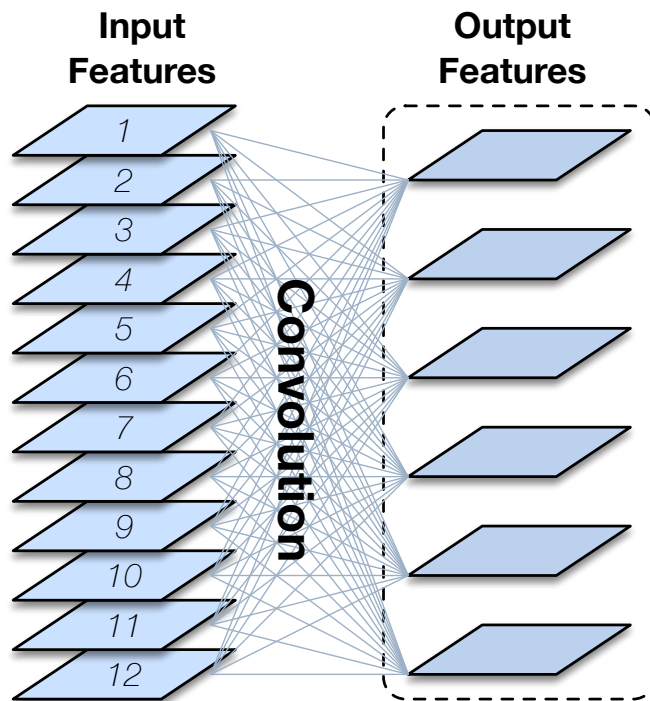
The background of the slide is a light gray color with a subtle, abstract pattern of dark gray nodes and lines. These nodes are connected by thin lines, forming a complex, interconnected network that resembles a neural network or a data structure. The pattern is more dense in some areas and more sparse in others, creating a sense of depth and complexity.

# Advanced Topics in Machine Learning: Convolutional Networks (Part 3)

Laurens van der Maaten and Anton Bakhtin

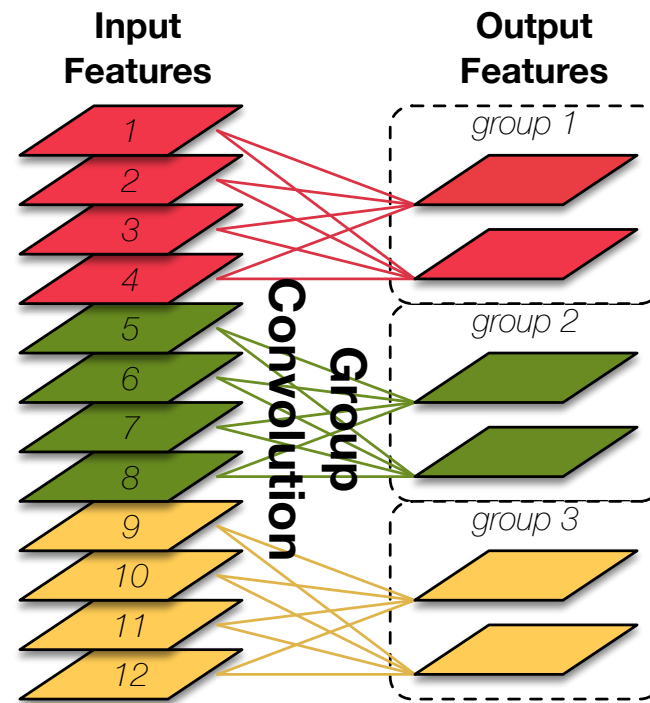
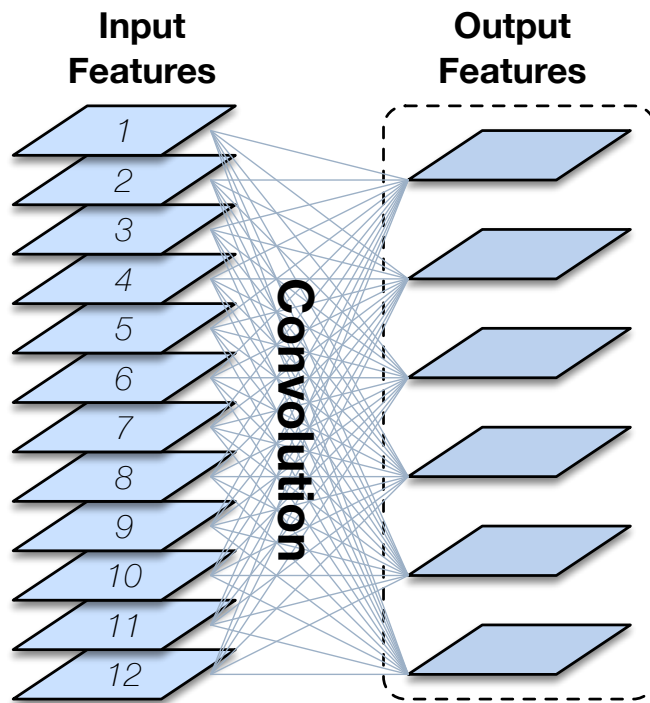
# Group Convolutions

- In **group convolutions**, not all input channels feed into all output channels



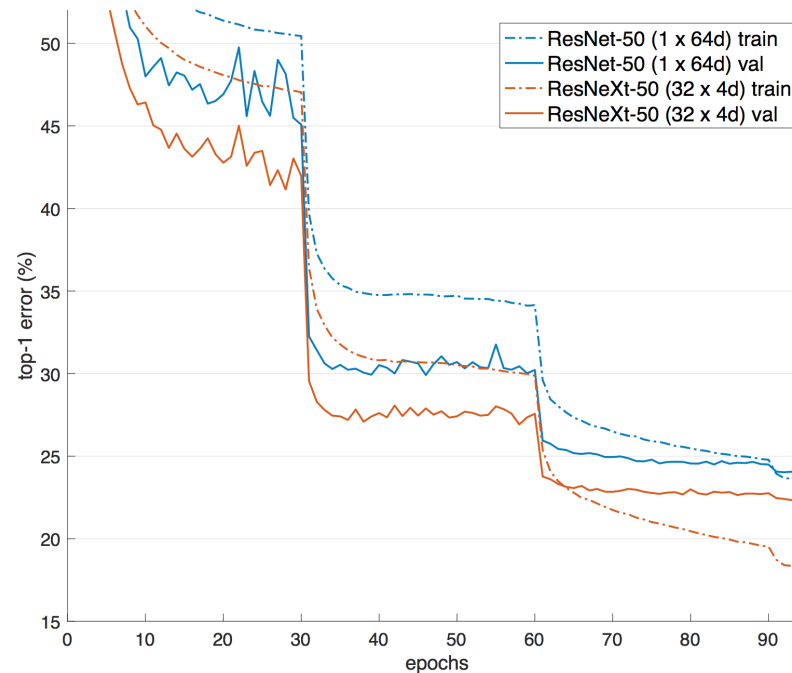
# Group Convolutions

- In **group convolutions**, not all input channels feed into all output channels:



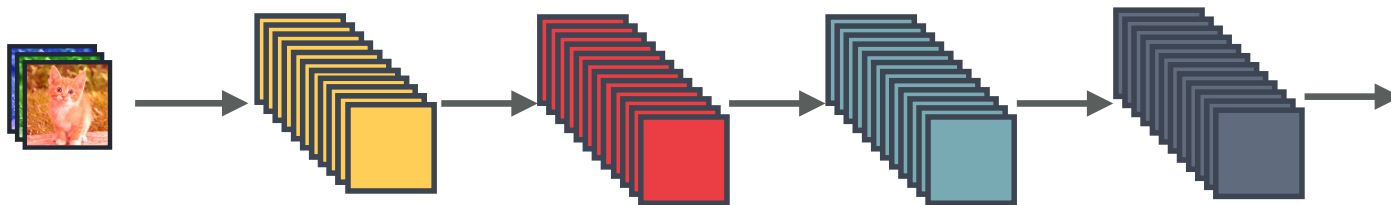
# Group Convolutions

- **ResNeXt** is a popular model that uses group convolutions
- Group convolutions generally give a better **compute-accuracy trade-off**



\* Figure credit: Kaiming He

# Standard connectivity



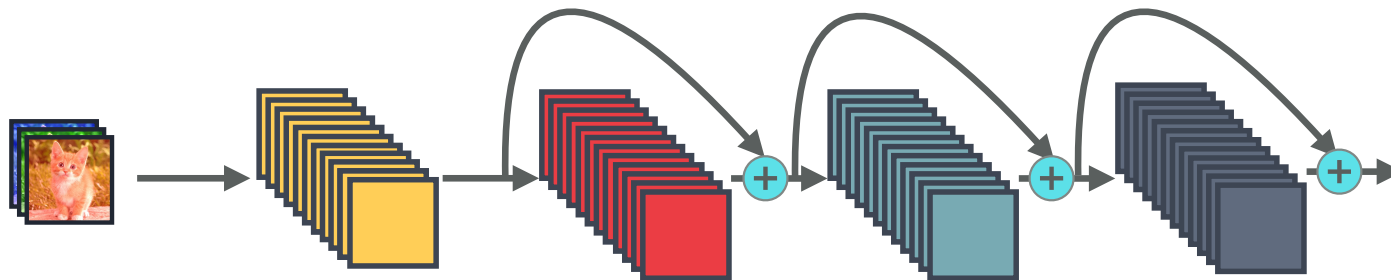
\* Slide credits: Gao Huang

# Residual connections

**Funny properties of ResNets...**

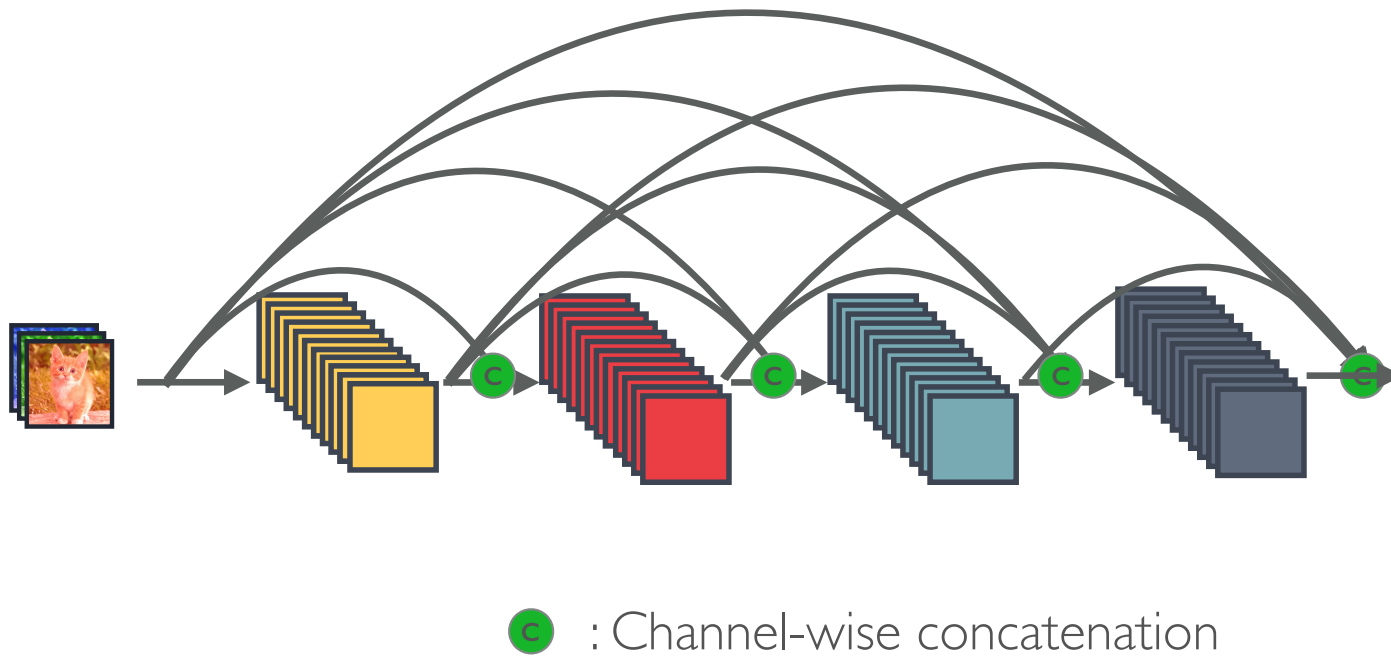
Identity,

propagation



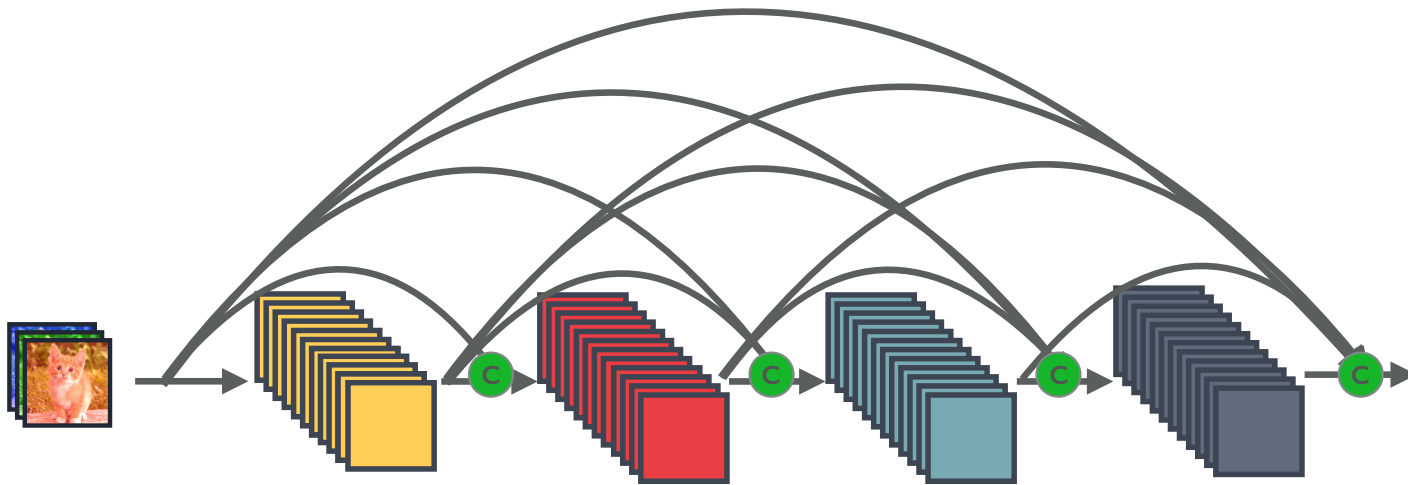
$\oplus$  : Element-wise addition

# Dense connectivity: DenseNet



\* Slide credits: Gao Huang

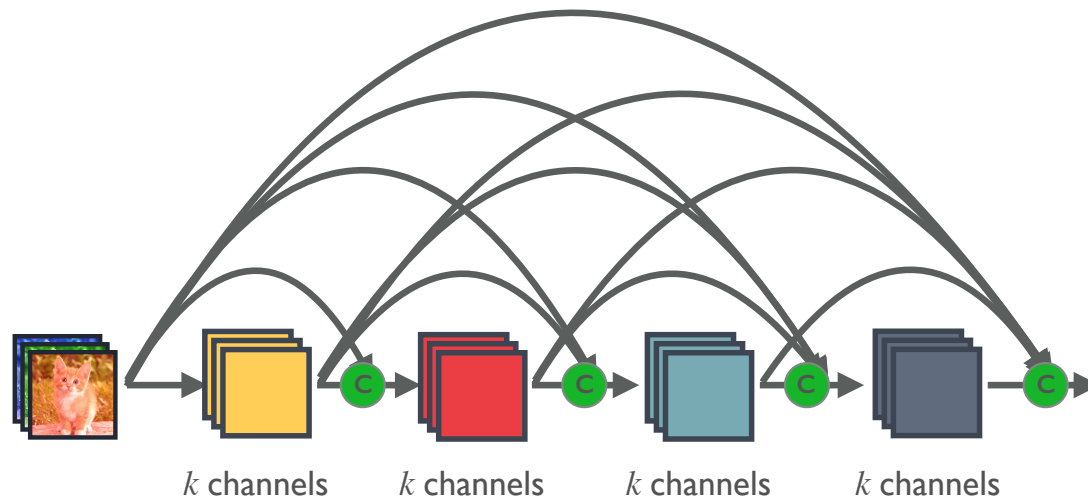
# Dense connectivity: DenseNet



\* Slide credits: Gao Huang



# Dense connectivity: DenseNet



$k$  : Growth Rate

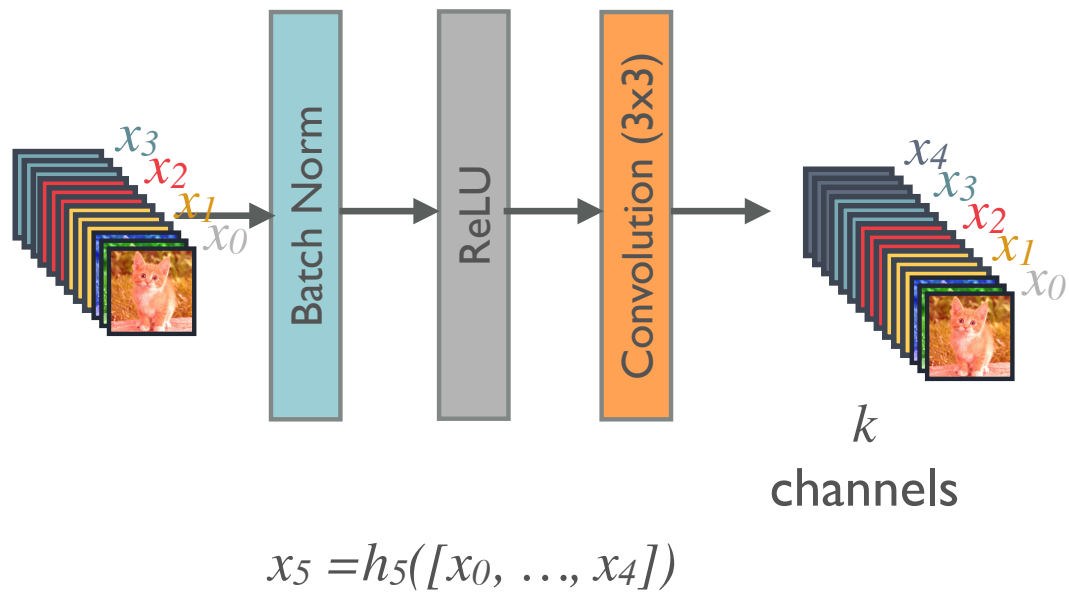
\* Slide credits: Gao Huang

# Forward propagation



\* Slide credits: Gao Huang

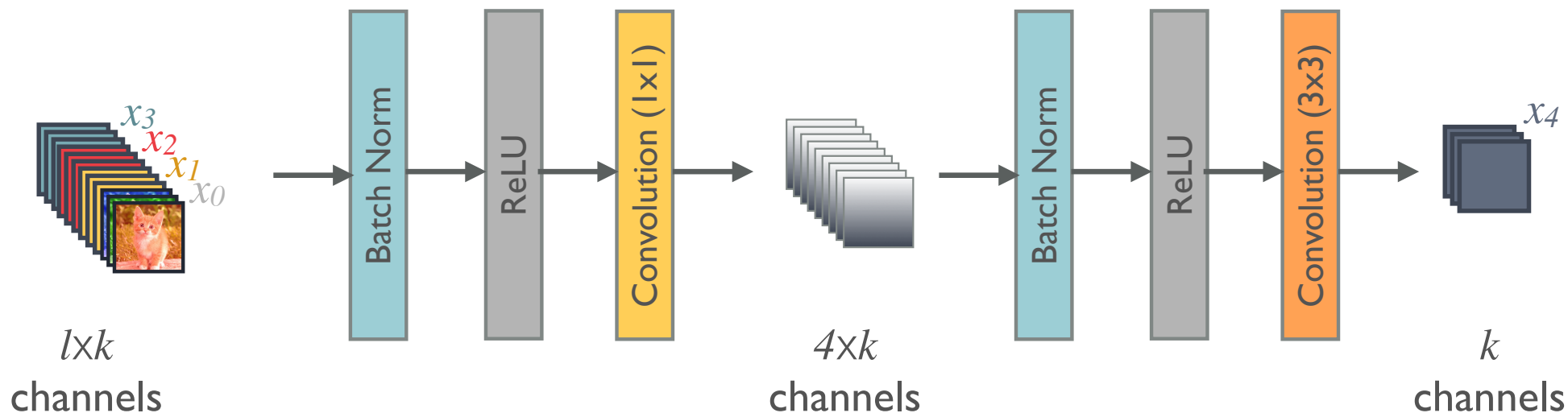
# Composite layer in DenseNet



\* Slide credits: Gao Huang

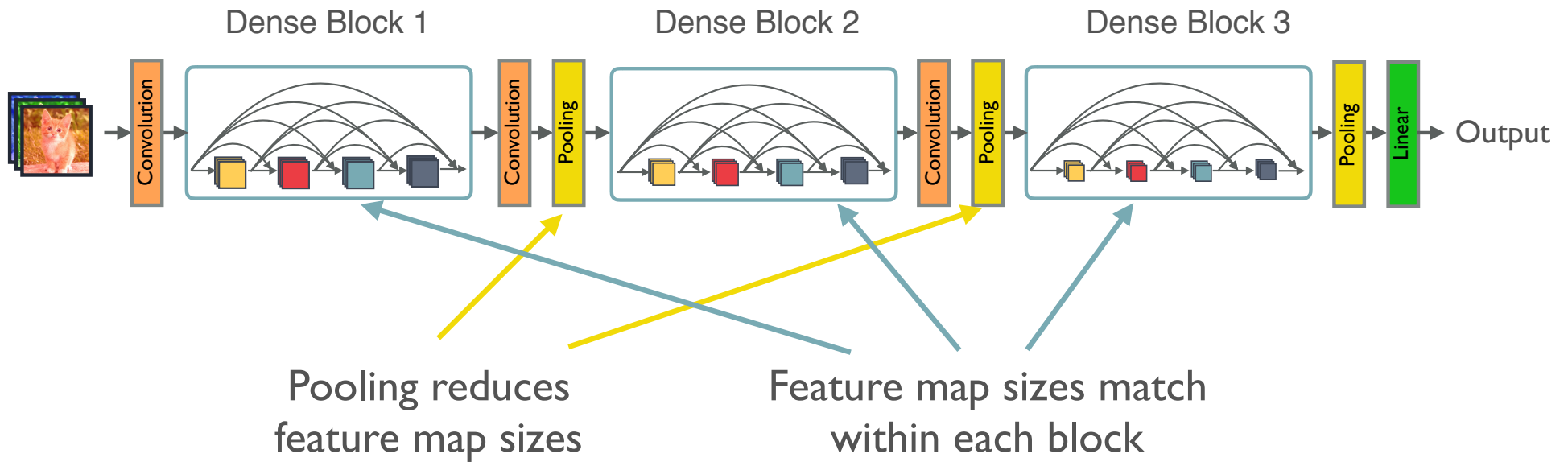
# Composite layer in DenseNet

With bottleneck layer:



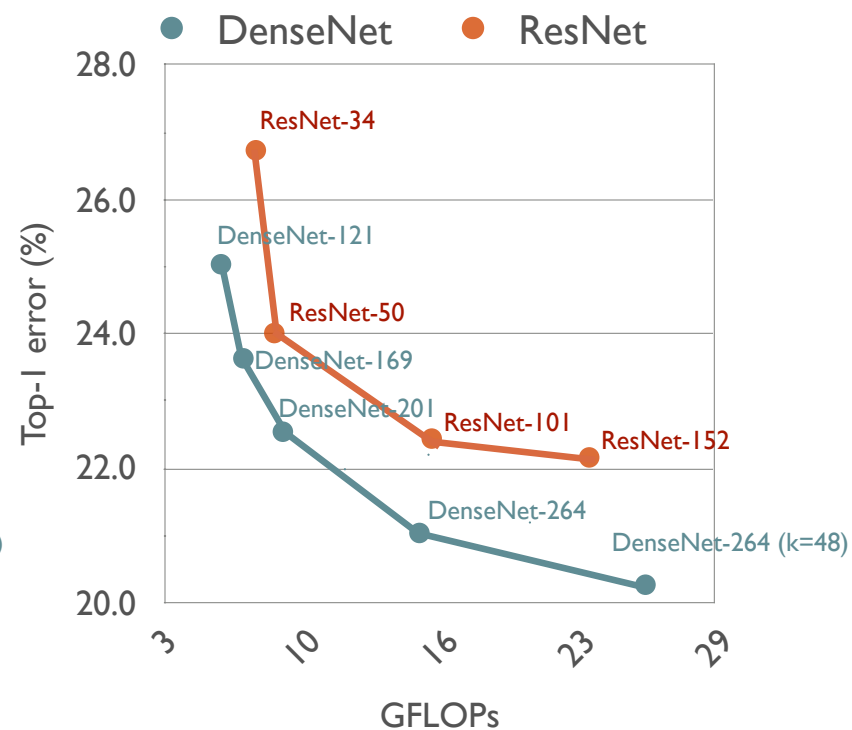
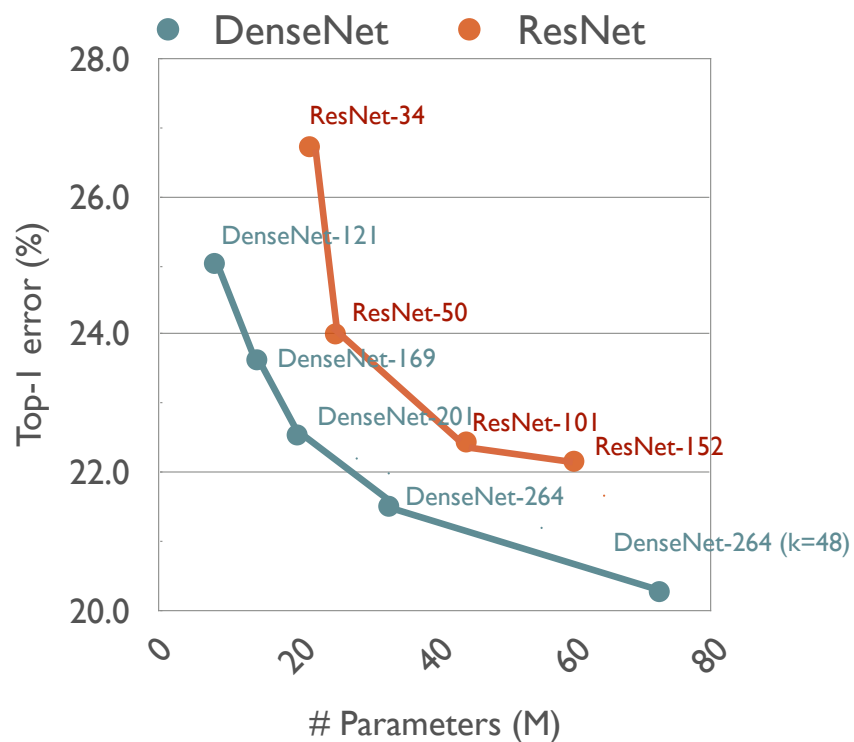
\* Slide credits: Gao Huang

# DenseNet



\* Slide credits: Gao Huang

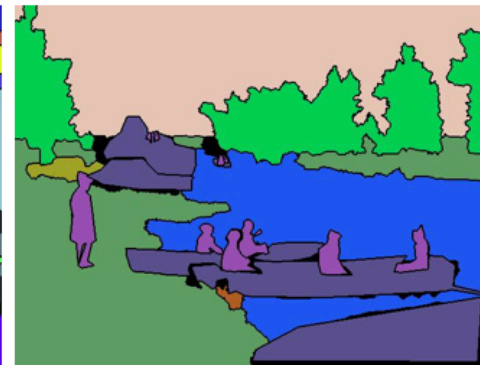
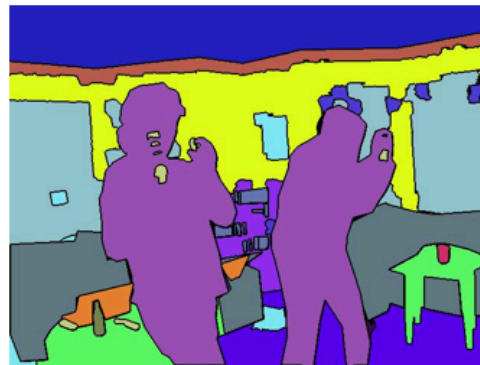
# Results: ImageNet



\* Slide credits: Gao Huang

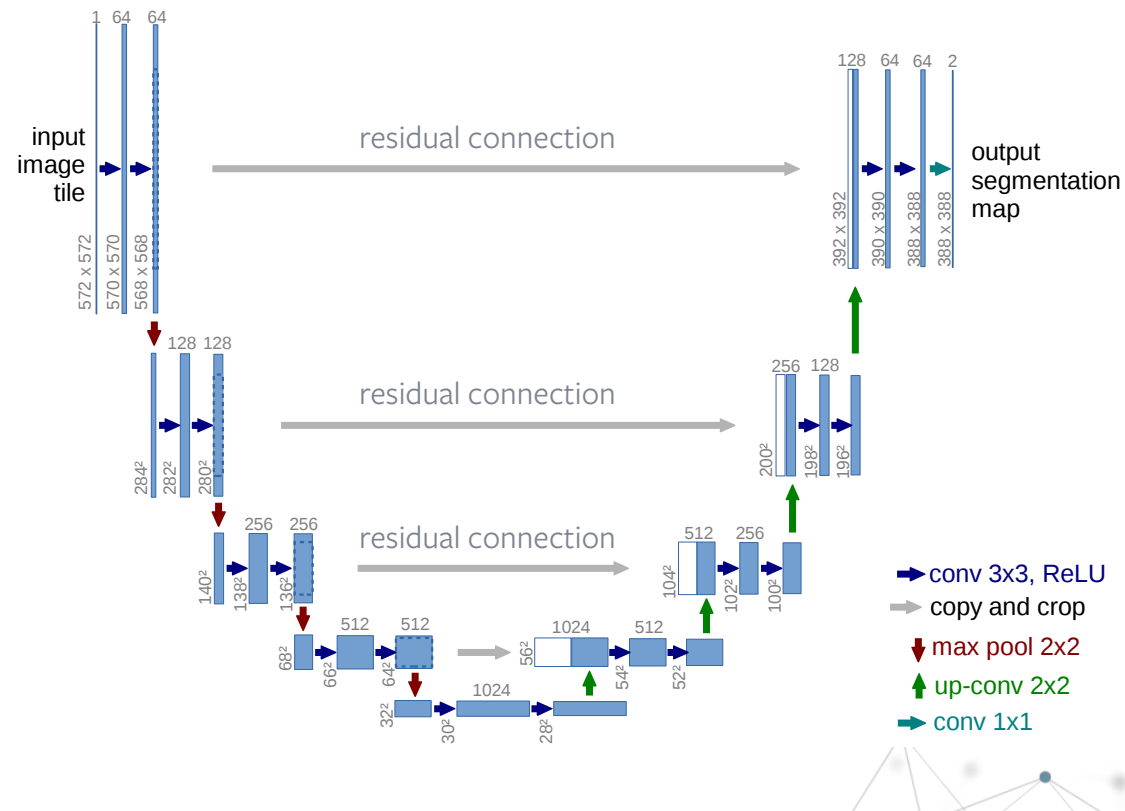
# Beyond image classification

- **Semantic segmentation:** Predict label for each pixel in the image



# Beyond image classification

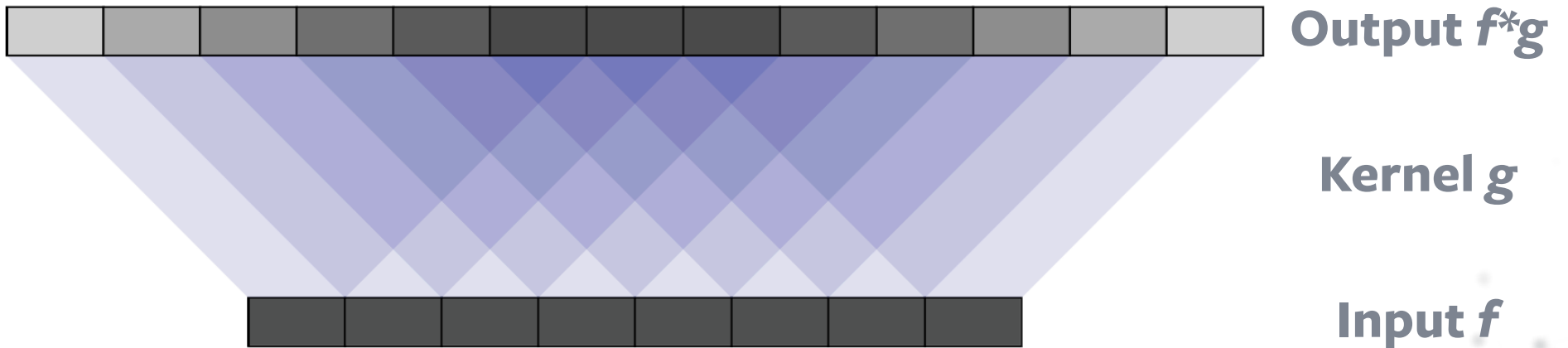
- **U-Nets** are an architecture designed for such problems:



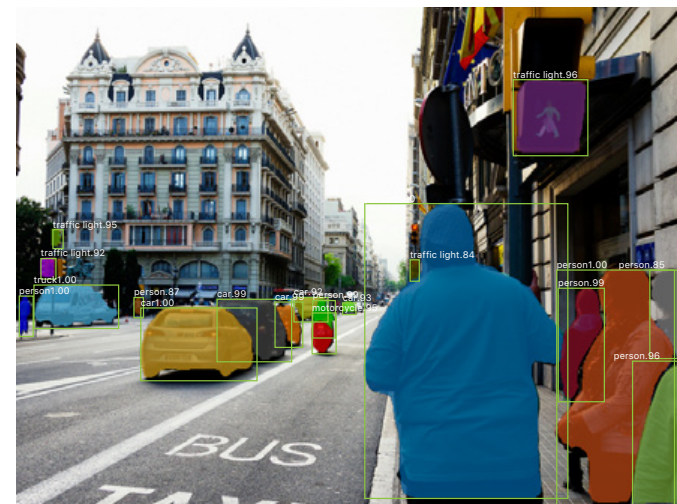
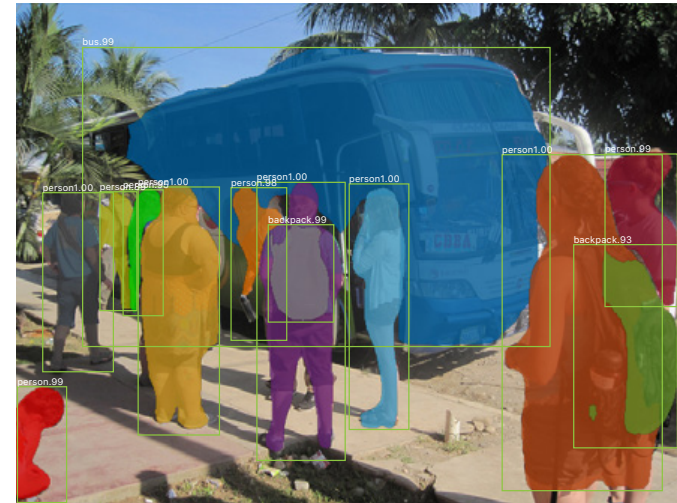
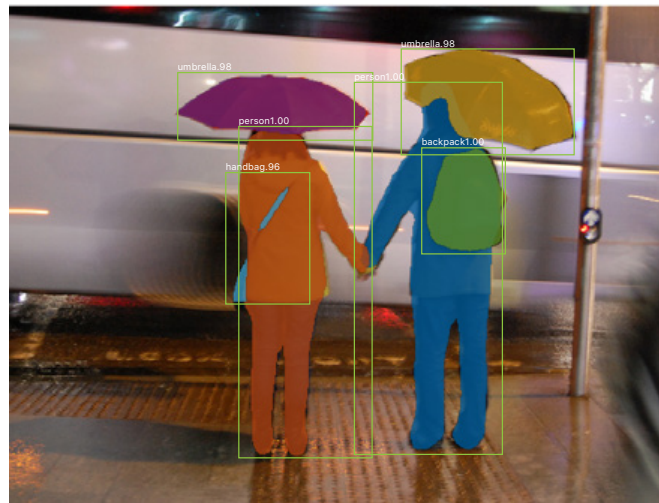


# Beyond image classification

- Main additional ingredient in U-Nets is **deconvolution**:



\* Credits: Chris Olah



\* Results obtained with Mask R-CNN.



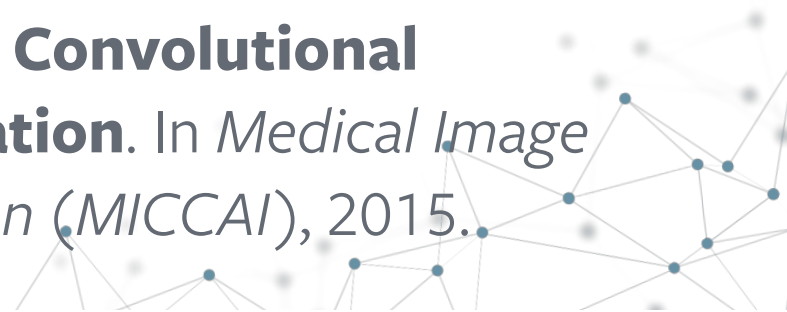
# Summary

- Dense connectivity is an efficient alternative to residual connectivity
- Group convolutions reduce parameters and computation by reducing number of interactions between input and output channels
- Deconvolution allows for building segmentation networks



# Reading material

- S. Xie, R. Girshick, P. Dollár, Z. Tu, and K. He. **Aggregated Residual Transformations for Deep Neural Networks**. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2017
- G. Huang, Z. Liu, L.J.P. van der Maaten, and K.Q. Weinberger. **Densely Connected Convolutional Networks**. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2017.
- O. Ronneberger, P. Fischer, and T. Brox. **U-Net: Convolutional Networks for Biomedical Image Segmentation**. In *Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, 2015.



The background is a solid blue color with a faint, abstract network pattern. This pattern consists of numerous small, light-blue dots (nodes) connected by thin, light-blue lines (edges). Some nodes are more densely connected than others, forming small clusters or triangles. The overall effect is a subtle, technical, and interconnected visual texture.

# Questions?