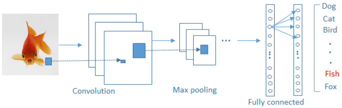
Deep Learning

CNN: Introduction



Learning goals

- What are CNNs?
- When to apply CNNs?
- A glimpse into CNN architectures

CONVOLUTIONAL NEURAL NETWORKS

- Convolutional Neural Networks (CNN, or ConvNet) are a powerful family of neural networks that are inspired by biological processes in which the connectivity pattern between neurons resembles the organization of the mamel visual cortex.

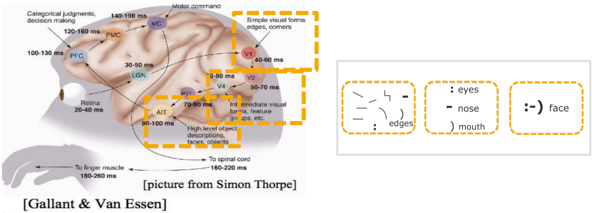


Figure: The ventral (recognition) pathway in the visual cortex has multiple stage: Retina - LGN - V1 - V2 - V4 - PIT - AIT etc., which consist of lots of intermediate representations.

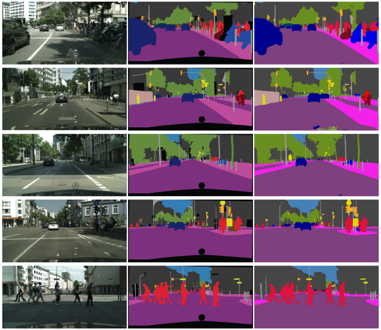
CONVOLUTIONAL NEURAL NETWORKS

- Since 2012, given their success in the ILSVRC competition, CNNs are popular in many fields.
- Common applications of CNN-based architectures in computer vision are:
  - Image classification.
  - Object detection / localization.
  - Semantic segmentation.
- CNNs are widely applied in other domains such as natural language processing (NLP), audio, and time-series data.
- Basic idea: a CNN automatically extracts visual, or, more generally, spatial features from an input data such that it is able to make the optimal prediction based on the extracted features.
- It contains different building blocks and components.

CNNS - WHAT FOR?

Figure: All Tesla cars being produced now have full self-driving hardware. A convolutional neural network is used to map raw pixels from a single front-facing camera directly into steering commands. The system learns to drive in traffic, on local roads, with or without lane markings as well as on highways (The Tesla Team, 2016).

CNNS - WHAT FOR?



(a) Image (b) Ground Truth (c) PSPNet

Figure: Given an input image, a CNN is first used to get the feature map of the last convolutional layer, then a pyramid parsing module is applied to harvest different sub-region representations, followed by upsampling and concatenation layers to form the final feature representation, which carries both local and global context information. Finally, the representation is fed into a convolution layer to get the final per-pixel prediction (Zhao et al., 2017).

CNNS - WHAT FOR?

Figure: Road segmentation: Aerial images and possibly outdated map pixels are segmented (Mnih & Hinton, 2010).

CNNS - WHAT FOR?

CNN for personalized medicine e.g tracking, diagnosis and localization of Covid-19 patients.

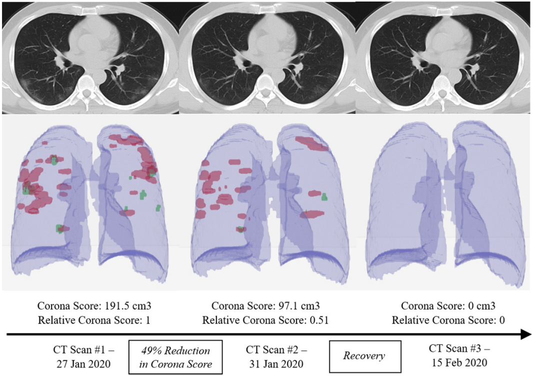


Figure: CNN based method (RadLogics algorithm) for personalized Covid-19 detection: three CT scans from a single Corona virus patient (Scudellari, 2020).

CNNS - WHAT FOR?

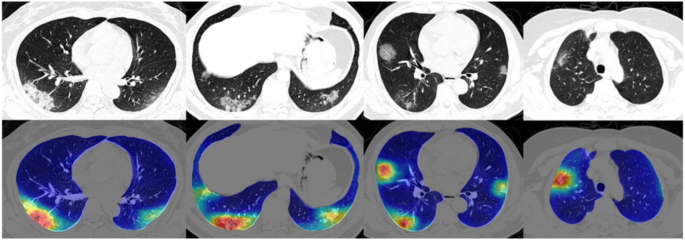


Figure: Four COVID-19 lung CT scans at the top with corresponding colored maps showing Corona virus abnormalities at the bottom using the RadLogics algorithm (Scudellari, 2020).

CNNS - WHAT FOR?

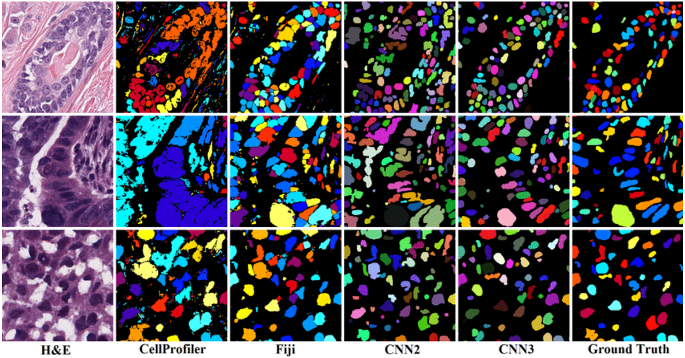


Figure: Various analyses in computational pathology are possible. For example, nuclear segmentation in digital microscopic tissue images enable extraction of high-quality features for nuclear morphometrics (Kumar et al., 2017).

CNNS - WHAT FOR?

Figure: Image Colorization: Given a grayscale photo as the input (top row), this network solves the problem of hallucinating a plausible color version of the photo (bottom row, i.e. the prediction of the network) (Zhang et al., 2016).

CNNS - WHAT FOR?

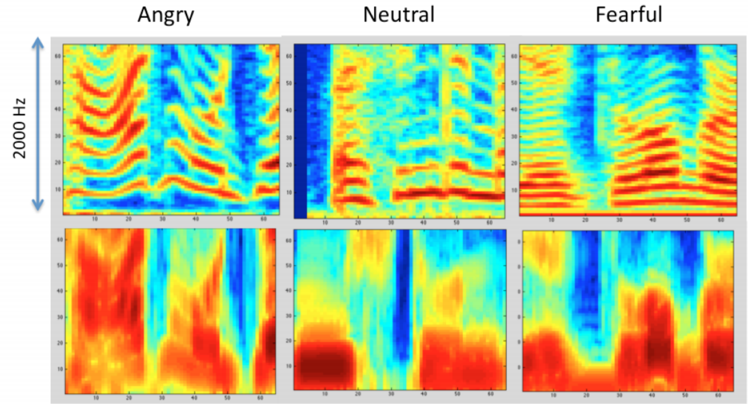


Figure: Speech recognition: Convolutional neural network is used to learn features from the audio data in order to classify emotions (Anand, 2015).

CNNS - A FIRST GLIMPSE

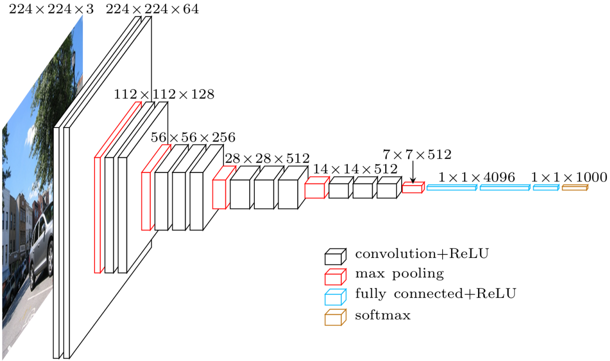


Figure: Example architecture (Simonyan & Zisserman, 2015)

- **Input layer** takes input data (e.g. image, audio).
- **Convolution layers** extract feature maps from the previous layers.
- **Pooling layers** reduce the dimensionality of feature maps and filter meaningful features.

CNNS - A FIRST GLIMPSE

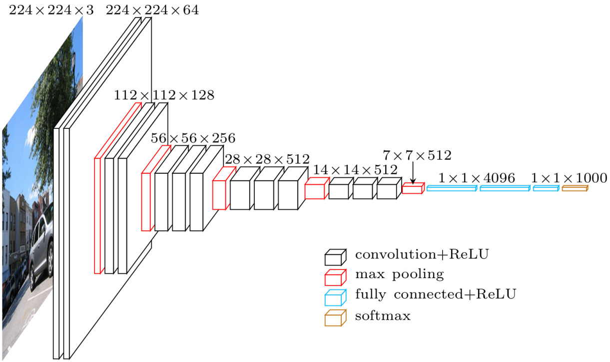


Figure: Example architecture (Simonyan & Zisserman, 2015)

- **Fully connected layers** connect feature map elements to the output neurons.
- **Softmax** converts output values to probability scores.

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