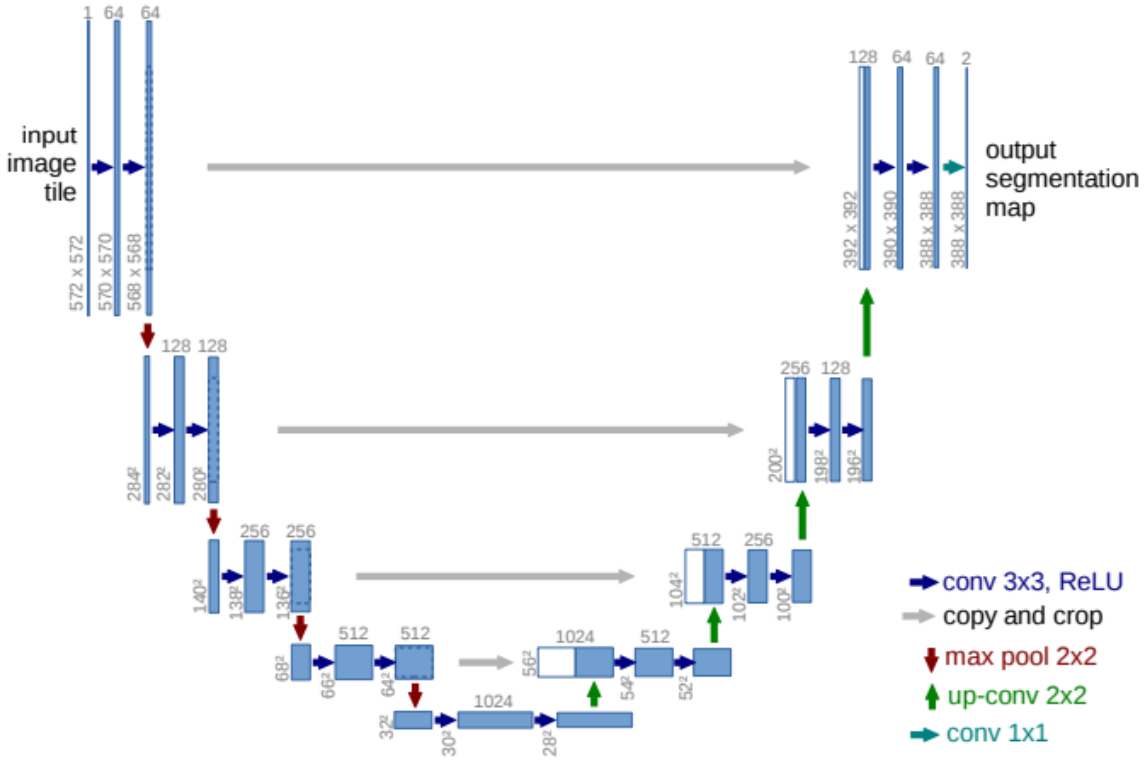
- #paper/to-read ~ 2015 CE ~ Convolutional Neural Network, CNN, Semantic Segmentation
  - **U-Net: Convolutional Networks for Biomedical Image Segmentation**
  - https://arxiv.org/abs/1505.04597
  - http://lmb.informatik.uni-freiburg.de/people/ronneber/u-net
  - Mentioned papers:
    - Fully Convolutional Networks
    - Very Deep Convolutional Networks
    - Hypercolumns for Object Segmentation
    - Cascaded Hierarchical Models
    - Delving Deep into Rectifiers

Summary

- The **architecture** consists of the contracting path used to extract locally global context and the expanding path used to mix that context information with the local features.



  - Features extracted on the contracting path are cropped before being mixed with local features due to the fixed-size reduction in

resolution (convolutions have no indent).
    - In the upsampling part, the model has many feature channels which allows it to propagate information efficiently to higher resolution layers.
    - Regions adjacent to the edge of an image are mirrored to account for the crop.
        - Large pictures are processed in tiles.
  - The output layer is a 1×1 convolution used to classify pixels.
- **Training Process** involves Data Augmentation, primarily by applying Elastic Deformations.
- A **weighted Loss** is used to make sure that the network learns to rigorously distinguish touching objects of the same class (e.g. cells in microscopical Medical images):

$$L = \sum_{\mathbf{x} \in \Omega} w(\mathbf{x}) \log(\text{softmax}_{\text{label}(\mathbf{x})}(\mathbf{x}))$$

  - Here, w is the loss weight for the feature map in a given pixel position $\mathbf{x} \in \Omega$.
  - Weights for the loss are pre-computed using Morphological Image Processing:

$$w(\mathbf{x}) = w_c(\mathbf{x}) + w_0 \cdot \exp\left(-\frac{(d_1(\mathbf{x}) + d_2(\mathbf{x}))^2}{2\sigma^2}\right)$$

    - Here, w_c is the weight map to balance the class frequencies, d_1 and d_2 denote the distances to the borders of the two nearest cells, $w_0 = 10$, and $\sigma = 5$.
