Efficient & accurate 4D reconstruction of mitral apparatus from echo

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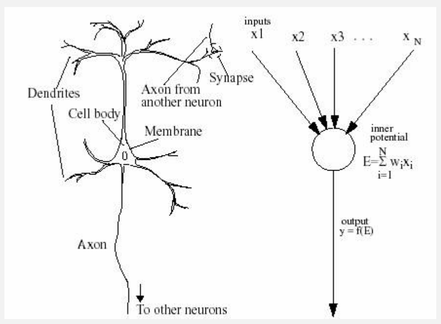
Goal

- To detect landmarks on 4D mitral valve images using neural networks.

- A 4D volume consists of N frames of 3D volumes,representing phases of a cardiac cycle. A 3D volume contains 2D slices in 3 directions (axial, sagital and coronal).
- The landmarks will be used to create finite element models. These models are used for patient specific simulations that may give access to research- or treatment insights.
- In literature we find that feature detection [1,2] is difficult to implement and include manual work.
- Neural networks could be used to train a model to detect the features automatically.

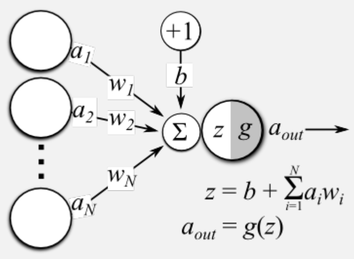
Methodology

The name neural networks resembles the architecture and function of biological neurons in the brain.

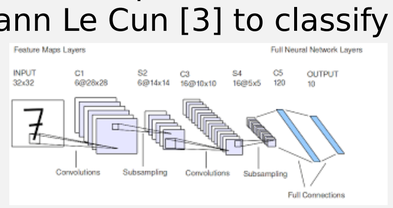


The biological neuron consists inter alia of dendrites, soma and an axon. Dendrites receive signals from neighboring neurons. The collection of these signals can be seen as an input vector x. The soma receive the input from the dendrites and add positive and negative ions. This can be seen as a summation function phi. The axon is a transmitter of a signal to other neurons if there is enough potential in the soma.

The artificial neuron is a function with a real-valued input vector x, a real-valued weight vector w and bias b.

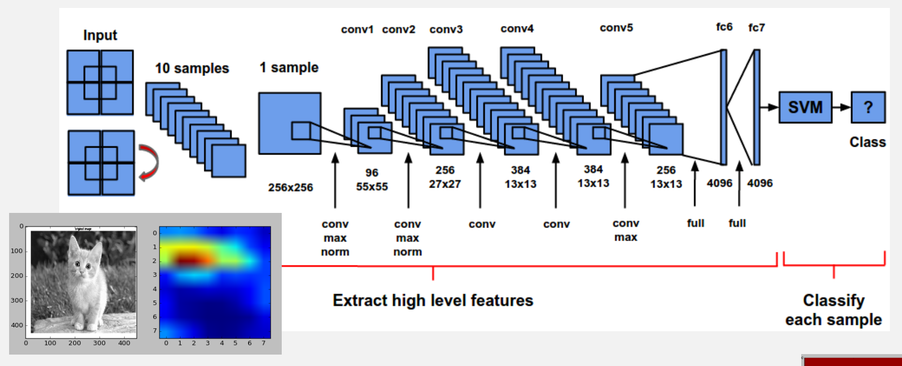


Deep learning can be accomplished with neural network and was first suggested by Yann Le Cun [3] to classify handwritten numbers (MNIST)

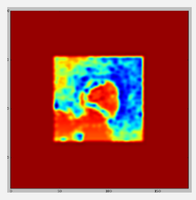


Feasibility study

<u>Can we extract pixels from a pre-trained model identifying a classification?</u>
This feasibility study used AlexNet[4], a neural net trained trained to classify 1.3 million high-resolution images in the LSVRC-2010 ImageNet training set .
We managed to extract classification information for the 7th hidden layer in the AlexNet architecture. With this information we generated a heat-map depicting the pixels that classify to a certain label.

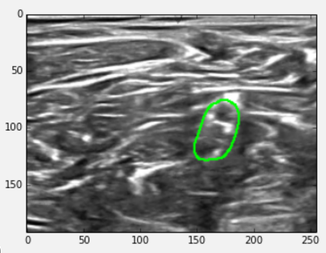


We also applied the same architecture to a minimal dataset of 2D ultrasound images of the axial view of the mitral valve annulus. From this neural network we extracted the heat-map .



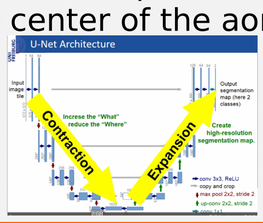
<u>Can we extract regions of interest from ultrasound images?</u>

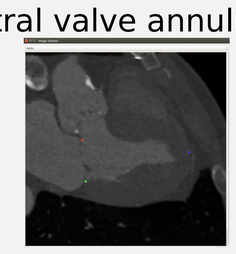
We participated to a Kaggle competition. The assignment was to accurately identify nerve structures from ultrasound. The dataset is given and consists of ultrasound images from the neck with golden standard masks identifying the region of interest.
The model was trained by applying a variation of u-net[5] and was ranked in the top third.



First use-case

<u>Can we extract the hinge points of the mitral valve annulus from a CT data set using a neural net?</u>
In this usecase we will train a variation of u-net to a CT dataset. The images depict the three-chamber-view which consists of the apex, the center of the mitral valve annulus and the center of the aorta valve.





Future plan

In order to get full understanding of neural networks and medical images, we will try our methodology on two use-cases: first the three chamber view (CT) as a proof of concept and later the mitral valve from 4D ultrasound images of multiple patients.

1. Schneider, Robert J., et al. "Mitral annulus segmentation from four-dimensional ultrasound using a valve state predictor and constrained optical flow." Medical image analysis 16.2 (2012): 497-504.
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5. Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer International Publishing, 2015.

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