ISIP 2020 Team Project

Sandro Silva, Gabriel Zala, Max Conradin Lutz

Introduction to Signal and Image Processing

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Introduction

Electrode arrays are implanted into the cochlea to treat patients with severe deafness. After implantation, a set of images is taken from the patient that is used to find the angular insertion depth of each electrode of the implant. This gives us information about which audio frequencies the Patient will be able to hear.

For each patient two images are provided, a pre- and post-operative CT-image that show the basal turn of the cochlea. The coordinates for both images correspond to each other.

The goal is to compute the angular insertion depth of each electrode of an implant. To be able to compute it one must extract the positions of each electrode and the centre of the cochlea spiral. The outermost electrode is the reference electrode with an angular insertion depth of 0^0 degree.

Methods

To get similar results for each image, the watermark on the top-left corner was removed and the intensity values of the grey-scale images were normalized so that the range lies between 0 and 255.

Find electrode coordinates

To get the coordinates of the electrodes, we processed each post-operative image individually. First, we normalized our image and applied a combination of median and gaussian filters to it, then we used a KNN-segmentation algorithm to compartmentalize our image into 10 discrete bins. We used KNN++-centre initialization for more consistent results, there is still some variation though.

Those pre-processing steps were all done to allow us to generate good binary images. The binary threshold was computed by estimating the total area that the electrodes would occupy in the image. With that information we set our threshold for binarization accordingly. Further on, we tried to remove some of the wire that emerges from the basal end of the cochlea by simply cropping it, as it is very bright in some images and could add more inconsistency to our results.

WIP: We were working on a watershed implementation until we ran out of time, we expect the watershed algorithm to significantly improve our binary images for electrode detection by splitting larger patches even before selectively eroding them.

After that, the contours of the binary images were drawn and the area that they represent was measured. To the largest area an erosion function was applied to get fused electrodes to split. The large area was replaced by the product of the erosion function. This step was repeated until the largest area is small enough to represent a single electrode.

The mass centre of each area was then computed which then represents the coordinates of an electrode in the image.

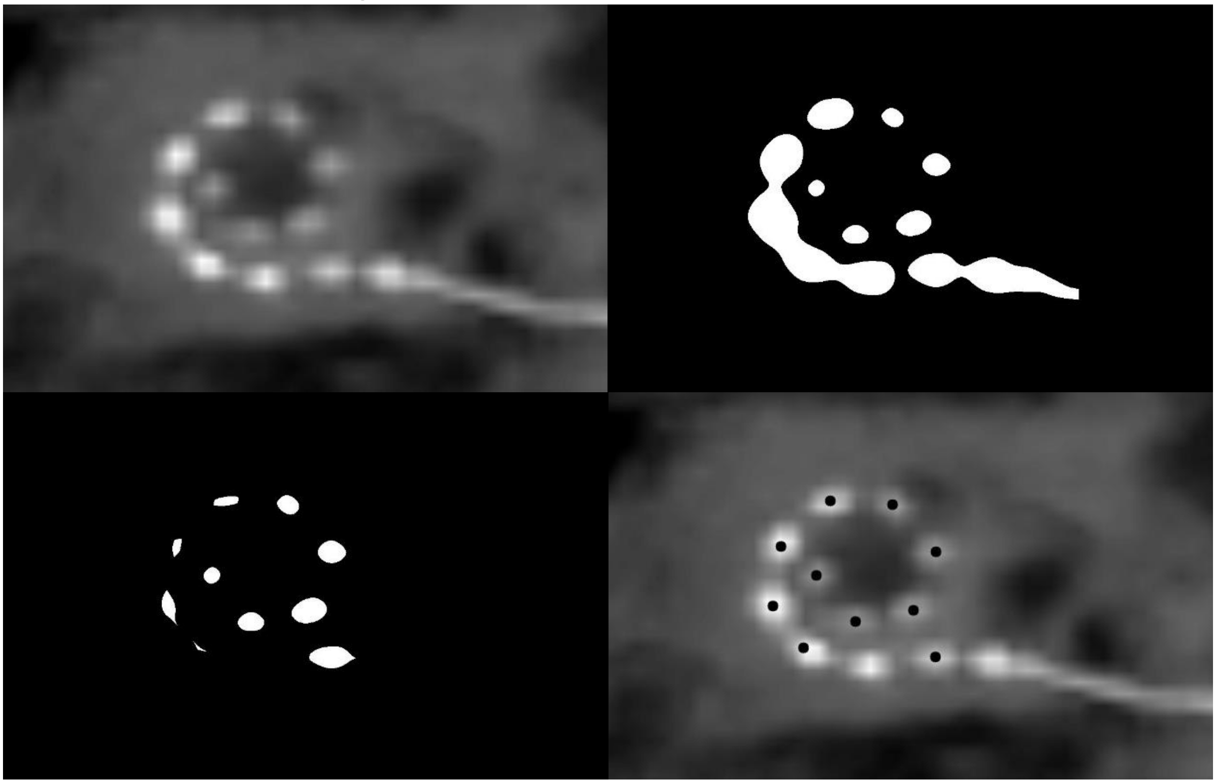

Figure 1 From left to right, top to bottom: cropped grey-scale image, binary generated by k-means segmentation, product of the individual erosion, electrode coordinates overlays the grey-scale post-operative image

Find cochlea centres

We applied a circular Hough-transform to the binary images to extract the centre of the cochlea spiral.

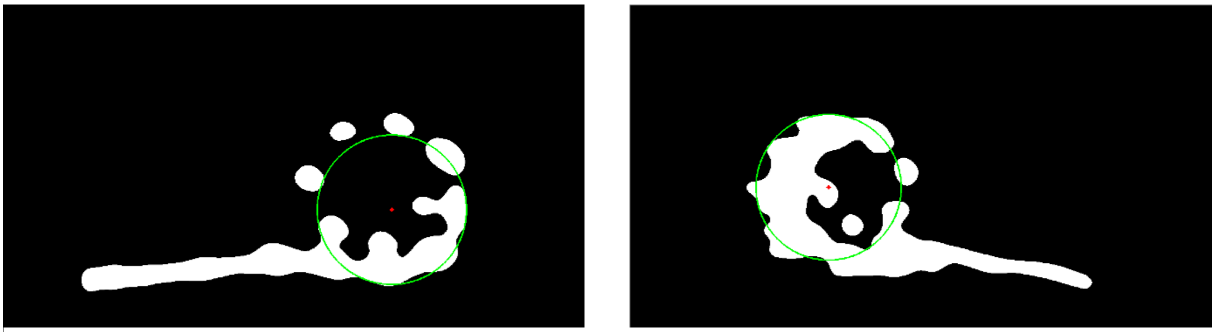

Figure 2 Hough-transform applied on different binary images. Even though the transform works much better on contours with a singular radius, it is also able to fit to multiple contours but with much less accuracy and consistency.

WIP: Hough Spiral transform – we were planning to implement a Hough spiral transform on the pre-images but couldn't figure out how to properly tilt either the matrices or the spirals in time.

Calculating angular insertion depth

For each patient, if the list of found electrodes was bigger than 12, the electrodes which were most distant to the cochlear centre were removed. Further the electrodes were labelled according their distance to the centre. Then the angular insertion depth was calculated by adding up the angles between two electrodes in regard to the centre, starting at the outermost electrode.

Results

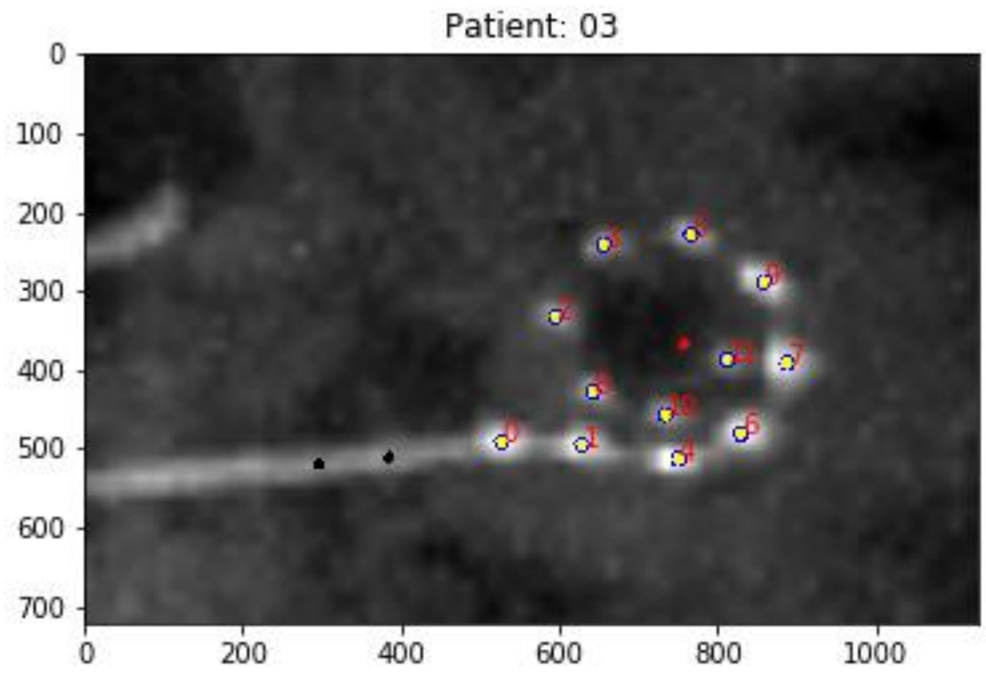

Figure 3 Example of our output. Black dots are false positives that were removed. Yellow dots mark electrodes. The labelling starts at 0 (outermost electrode) and should increase the further we go into the spiral towards the centre.

The angular insertion depths and the coordinates to every electrode can be found in the excel file that is provided.

Discussion

We used a k-means clustering algorithm to segment the post-operative grey-scale images. The initialization of the centroids is random to a certain degree. Because of that the centroids have the possibility to get trapped in a local minimum, which can net different results in each iteration of the algorithm.
During the processing of the images, electrodes deeper down in the cochlea are lost sometimes because their intensities were too low. To fix that issue we tried several

things like convolution of the image with a kernel that maximises the local max intensities. Unfortunately, we were not able to sufficiently improve the results that way and will need to further optimise our normalization parameters to achieve the desired result.

A big difficulty was also the high intensity of the wire of the electrode array. It often has the same intensity as the electrodes itself (figure 2). We tried to cut off as much as possible of the wire, but it would need to be done in a smarter way because it's size and orientation is different in most images.

The problems we had with our detection algorithms meant that we ended up with data, that could not be confidently interpreted by our electrode-labelling algorithm, which means that we would need a better labelling algorithm to deal with our current detection methods.

To sum it up, we were unable to achieve a precision, that would allow us to confidently measure cochlear implant electrode angular insertion depth from the given data.

In hindsight we would take another approach to this task. One promising approach as example would be to first create a ground truth of the data we were given.

The biggest issue in general was probably the special .png format of the post images though. We didn’t understand the implications of it at the start of development, and ultimately never found out how to properly read the files in the first place (none of the libraries we know seem to support it, we ended up using different types of approximations, but were never able to access the “depth” data of the electrodes). This caused many problems that propagated themselves through the whole process and cost us absolutely massive chunks of time in debugging.

Contributions

Sandro: data loading, electrode labelling and angular insertion depth calculations

Gabriel: pre-processing (k-means segmentation, individual binarization of images)

Conradin: Hough-transformation for circle detection, individual erosion of binary images