

# An Image Processing Chain for a Three-Dimensional Reconstruction of Basal Cell Carcinoma.

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## Abstract

Histological sections are used regularly for tissue study in clinical surgery. Such a restricted two-dimensional view of, e.g. tissue anomalies, can never reveal as much detailed information as that found in the original 3-d specimen. Therefore a 3-d elevation of interesting features would significantly improve the insight into both spatial extents and local distributions. Actually, a deeper knowledge of its properties is missing. We provide a chain of image processing steps starting from slices and describing the way to a 3-d volume reconstruction of the extracted carcinoma.

## Method

We use an excised specimen of a basal cell carcinoma embedded in paraffin and consecutively sliced in vertical direction. These slices were then stained with Hematoxylin-Eosin (H&E) and digitized with a Zeiss Mirax Slide Scanner. The image processing chain starts with a first rigid registration (including scaling).

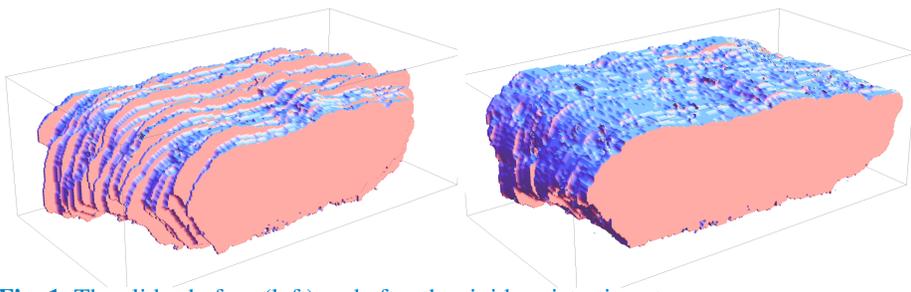


Fig. 1. The slides before (left) and after the rigid registration step.

After this first registration step the images are processed through a Total Variation Filter for edge-preserving smoothing. The filter uses the estimated standard deviation of the noise as only input parameter and is estimated from background parts of the image. The purpose of the smoothing is to get a consistent segmentation result as noise and color variations in the images will be blurred to a certain level after application. The results of the filtering are then segmented using the Fuzzy C-Means Segmentation. We chose this segmentation because it is very likely that in Hematoxylin-Eosin-stained slides the segmentation-classes of tumorous and non-tumorous parts overlap in color-space [1]. The Fuzzy C-Means Segmentation can handle this behavior and therefore provided constant good results throughout the whole image stack.

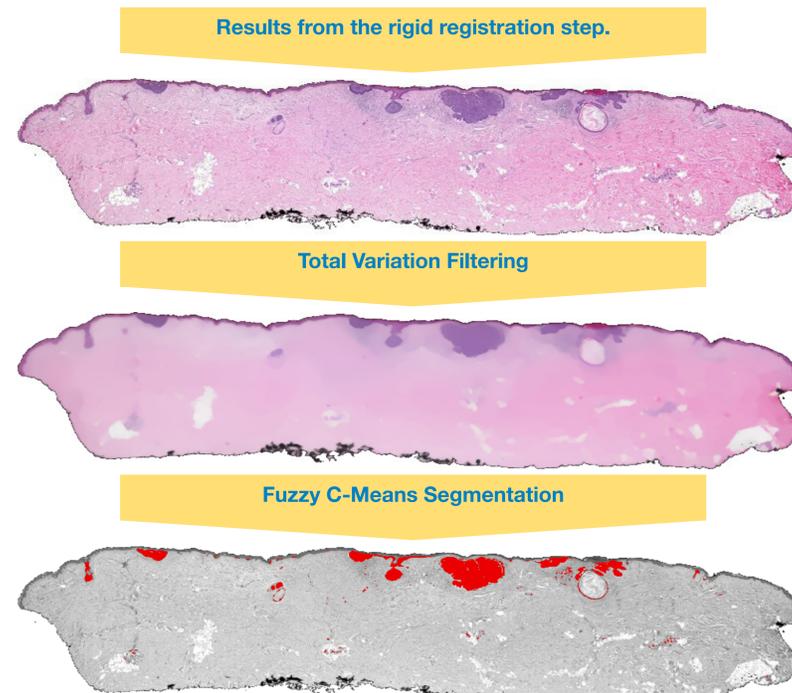


Fig. 2. A flowchart for the main steps of the tumor segmentation. To demonstrate the edge-preserving behavior of the Total Variation Filter we took extreme filter parameters for this example.

When the segmentation is done, a second registration on the tumor classes is done fitting the corresponding tumor parts in adjacent slides onto one another. This non-linear registration method is based on the optical flow. It minimizes a joint registration criterion consisting of a distance measure (here the sum of squared differences) and a smoothing term.

$$\min_{\vec{u}} (\mathcal{D}(\vec{u}) + \alpha \mathcal{S}(\vec{u}))$$

where

$$\mathcal{D}(\vec{u}) = \frac{1}{2} \int_{\Omega} [T(\vec{x} - \vec{u}(\vec{x})) - R(\vec{x})]^2 d\vec{x}$$

$$\mathcal{S}(\vec{u}) = \frac{1}{2} \sum_{i=1}^2 \int_{\Omega} (\Delta u_i)^2 d\vec{x}.$$

Using the calculus of variations, the solution for this equation will require to solve a system of 4th order partial differential equations. Different approaches are possible (see e.g. [2, 3]). Here we have used the method that was mentioned in [4] and was described in more detail in [1]. We registered the whole set of images from the serial section so that every slide is registered onto its (previously registered) predecessor. 3-d volume reconstruction can then be built by putting the image data of all slides into a single three-dimensional matrix.

## Results

Figure 3 shows the complete 3-d reconstruction of the tumor with the same point of view as in figure 1. Tumor pattern from the sample in figure 2 can be observed in the front of figure 3. Since this serial section provided only 36 slices for the reconstruction the ratio of image size to slide thickness is changed in figure 3.

Compared to other reconstruction chains (e.g. [1]) we did not clean the result. The small thin „rod“ on the left of figure 3 for instance is a hair-follicle. Even pathologists have to check adjacent slices when hitting a hair-follicle since form and color is sometimes very close to tumor.

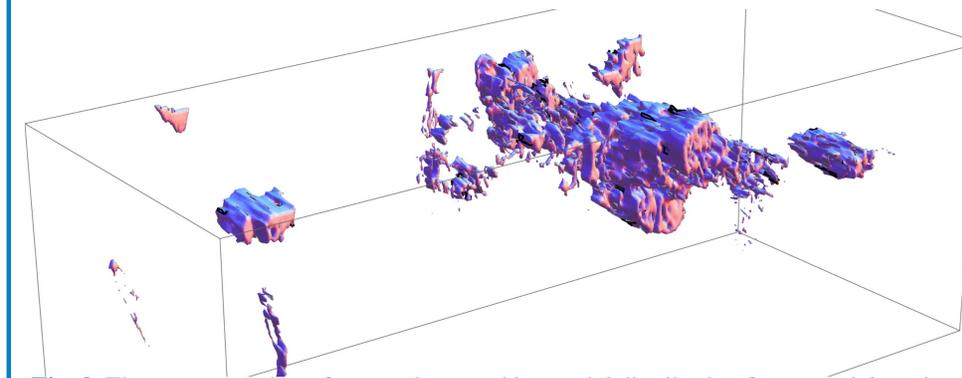


Fig. 3. The reconstruction of tumor shape and its spatial distribution from a serial section of a specimen containing a basal cell carcinoma.

## References

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