Volume Estimation and Tracking Over Time (VETOT): Innovative software applied to the study of uterine fibroid growth dynamics

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Volume Estimation and Tracking Over Time (VETOT) software has been developed to track and quantify the evolution of tumors over time. This innovative and user-friendly tool was used to perform volumetric measurements for the Fibroid Growth Study (FGS), an effort to further our understanding of uterine leiomyoma growth dynamics.

VETOT combines an assisted rigid registration and a segmentation framework, which allows the user to compare tumors visible on consecutive MR scans of the same subject acquired at two different time points, referred to as t and t+1. The overall procedure implemented in VETOT can be divided in two main parts:

- Identification of corresponding tumors from consecutive MR scans
- Volumetric measurement of the tumor identified in the image acquired at time t+1

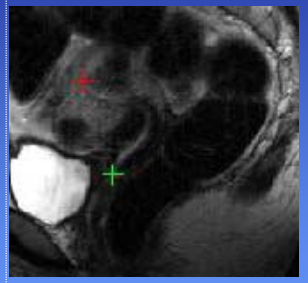

Figure 1: Identification of corresponding tumor

Our approach requires the selection of four landmarks used for an initial alignment of the uterus. The alignment is refined using a mutual-information rigid registration algorithm. The uterus mucosa was selected as a morphological landmark as it consistently appears in each MRI acquired for this study. The registration process allows identifying corresponding tumors and visualizing changes over time (figure 2).

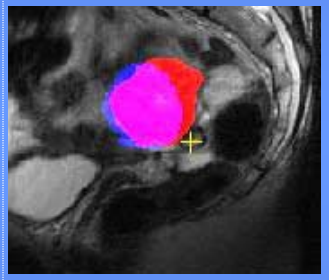

Figure 2: Comparison of tumors at two different time points

This screenshot illustrates the comparison of a tumor extracted from an MRI acquired at 12 months (red) with the segmentation of the corresponding tumor obtained from an MRI acquired after enrollment in the study (blue). The pink region represents the volume intersected by both segmentations. A visual inspection of the data suggests that volume changes did not occur evenly.

The initial identification of corresponding tumors is performed by using the registration framework to align the mucosa of the uterus visible in consecutive abdominal MR scans. The mucosa was chosen as landmark because it remains consistently visible throughout MR scans gathered for the FGS and moves with the entire uterus. The optimal transformation returned by the registration process is used to resample the tumor extracted from the scan acquired at time t and overlap the resulting tumor on top of the image acquired at time t+1. The overlapped tumor allows identifying the tumor at time t+1 corresponding to the tumor studied at time t.

Volumetric measurements of the tumor at time t+1 are performed using the segmentation framework provided by VETOT. This framework provides tools to perform reliable volumetric measurement of tumors and gather other tumor characteristics as its location within the uterus coordinate system. The comparison of results obtained for consecutive time points gives a quantification of the growth factor for the tumor of interest.

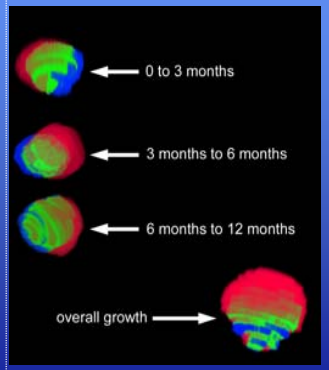

Figure 3: Overall growth visualization

This figure illustrates the visualization of data generated by VETOT using VolView software developed by Kitware, Inc. The green voxels represent the common volume intersected by the reconstructed volume of the same tumor obtained at two consecutive time points. Blue voxels belong only to the tumor at time t, and red voxels belong only to the tumor used for comparison at time t+1. In this particular case, we can notice a significant growth of the uterine fibroid between three months and six months. This observation correlates with volume measurements, which are respectively 27 cm3, and 40 cm3.

The segmentation framework of VETOT provides several options, including a semi-automatic approach that facilitates parameterization of the complex underlying segmentation algorithm, and a manual segmentation tool that allows processing low quality datasets.

Validation experiments demonstrated that VETOT can estimate tumor volume within a 5% error margin. The use of the semi-automatic segmentation feature reduces the variability between users to approximately 10% and makes the overall volume quantification procedure significantly faster. We are currently developing an algorithm to compute a growth probability map for uterine fibroids with respect to their location within the uterus coordinate system defined by the mucosa.

Figure 4: Validation study

The accuracy of VETOT was evaluated by performing repeated volumetric measurements from a MR scan of a container filled with a known amount of water. The resulting average volume was compared with the actual amount of water.

The variability of VETOT was estimated by comparing measurements obtained from a group of seven users for a set of three identical tumors. Participants were not allowed to see results obtained by others prior to the experiment.

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