Creating Virtual 3-D Laryngeal Models from CT and Histological Data in MATLAB

Ted Mau

Department of Otolaryngology-Head and Neck Surgery, Univ. of Texas Southwestern Medical Center
Dallas, TX

Abstract

Physiologic movement of the vocal fold/arytenoid complex occurs in three dimensions. However, most current modalities of clinical and imaging assessment of laryngeal function rely on two-dimensional information. This memo describes methods of producing 3-D models in MATLAB from 2-D images to facilitate our understanding of vocal fold posture and arytenoid motion.

Download updates to this memo can be downloaded at http://www.vocalfolds.org.

Keywords: CT, histology, 3D, injection, arytenoid, vocal folds

1. Introduction

Insight into laryngeal function in health and disease comes from assessment of static or dynamic laryngeal anatomy. In live human subjects or excised larynges, X-ray computed tomography (CT) scans provide good definition of the cartilaginous framework when the cartilage is sufficiently calcified. Detailed definition of the soft tissue components, for example the layers that constitute the vocal fold mucosa and the intrinsic laryngeal muscle connections between the cartilaginous elements, is revealed in serial histology sections obtained from specimens. In both cases, the information is largely conveyed in two-dimensional formats even though three-dimensional information is intrinsic in the stack of two-dimensional images. Display of the data in 3-D should facilitate our appreciation of the spatial relationships among the soft tissue and cartilaginous components that make up the larynx. 3-D models should also yield insight into spatial changes induced by surgical procedures.

The purpose of this report is to describe the process of generating 3-D virtual laryngeal models from CT or histological data in MATLAB. Please also see Technical Memo No.2, "Building Vocal Fold Solid Models from MRI, CT, and Histological Data", for an alternative method of building virtual models.

2. Selective Image Extraction from CT Images

CT images in common graphics formats (e.g. JPEG, BMP) are used as inputs. DICOM images can be used as well, see Technical Memo No. 3. 2-D. Images with the highest resolution based on the direction of scanning should be used and the pixel size should be known from the field of view (FOV) of the scanner acquisition so that the virtual objects have absolute measurement units.

The first step is to extract the relevant object(s) from the CT images. For example, the outline of the arytenoid cartilage, thyroid cartilage, injected material, implant, or even the mucosal surface can be separately extracted (Fig. 1). There are different methods to achieve this using a variety of image editing software. The author used the Extract filter in Adobe Photoshop CS2 (version 9.0, Adobe, San Jose, CA) using hand-drawn masks. The image contrast can be adjusted to better define the object boundary. From each stack of raw CT images, a new series of stacked images are created to correspond to each object of interest.
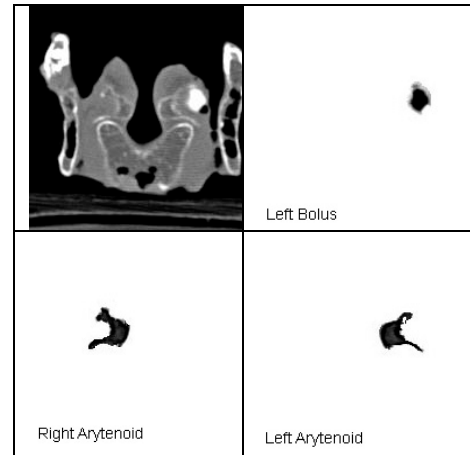

Figure 1: Selective extraction.

3. Creating Virtual Model in MATLAB

Each series of stacked images representing an object, e.g. the right arytenoid, is imported into MATLAB as a 3-D data matrix. Patch objects are created using the ISOSURFACE function to display the object of interest as a 3-D surface. The objects can be manipulated independently from one another for both display and modeling purposes.
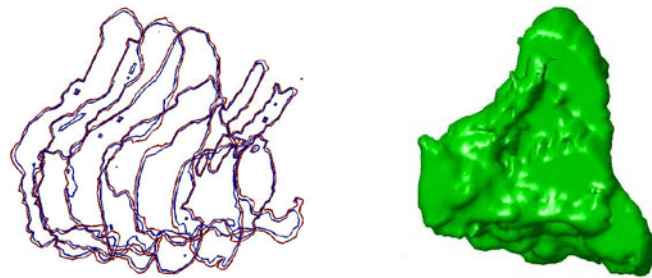

Figure 2: Example of creating 3-D virtual model from two-dimensional sections. Left: Series of sections. Right: Virtual model represented by isosurface of volume data.

4. Selective Image Extraction from Histology Data

The same approach used for CT images can also be used to create virtual objects from histology sections. In the example shown, the raw data consisted of digitized whole-larynx histology sections. Pixels corresponding to the cricoarytenoid ligament were selected or highlighted in Photoshop. Three series of stacked images were created to correspond to the ligament, arytenoids, and cricoid. These were then assembled in MATLAB and the isosurface objects displayed. Since only three sections contained the ligament the final model was of low resolution, but still illustrated the spatial position of the ligament better than the original histology sections.
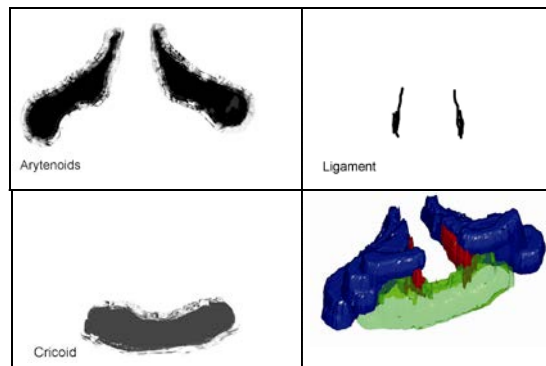

Figure 3: Bottom-Right: Cricoarytenoid ligaments (Red), arytenoids (Blue), cricoid (Green).

Literature

T. Mau and K.T. Weinheimer. Three-dimensional arytenoid movement induced by vocal fold injections. Laryngoscope 120:1563-1568, 2010.

T. Mau, J. M. Brewer, S. Gatzert, and M. S. Courey. Three-dimensional conformation of the injected bolus in vocal fold injections in a cadaver model. Otolaryngol Head Neck Surg 144:552-557, 2011.

Acknowledgements

Use Agreement

The scripts, images, model, and text contained in this memo are open to use by the public as a service and part of the National Resource of Laryngeal Data (supported by the National Institute of Deafness and other Communicative Disorders, and hosted by the National Center for Voice and Speech). However, we ask the reader to respect the time and effort put into this manuscript and research. If the text, images, or included scripts are used, the user agrees to reference to this document, the NRLD, and the source of the original data. We also ask the users to consider contacting the original contributors of the data and give them the right of refusal to (1) participate on papers using the data and (2) have their supporting project acknowledged. The user agrees to freely share with the NRLD any extension software build on the data contained.

Revisions

1.0   Ted Mau: Main Content