Automatic volume estimation of the thyroid gland using 2D Ultrasound Imaging

presented by

SUBBARAO NIKHIL NARAYAN
School of EEE

Supervisor: Assoc. Prof. Pina Marziliano, School of EEE
Co-Supervisor: Prof. Nadia Magnenat Thalmann, Institute for Media Innovation
Clinical Collaborator: Dr. Christopher Hobbs, Dept. of Otorhinolaryngology, Tan Tock Seng Hospital, Singapore

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Outline

• Fundamentals of Thyroid Gland
• Volume estimation
• Proposed method on 2D US imaging
• Experimental results
• Future work
Fundamentals

Anatomy

- Normal Thyroid
  - Anatomy of the neck
  - Structures:
    - Jugular vein
    - Thyroid cartilage
    - Superior thyroid arteries
    - Carotid artery
    - Thyroid gland
    - Thyroid veins
    - Trachea

Functions

- Hormone Regulation
- Iodine Metabolism
- Controls energy usage in body

Neck Lumps

Pathophysiology

- Hypothyroidism
- Hyperthyroidism
- Benign Thyroid Disease
- Thyroid Cancer

Confirming Diagnosis

- Fine Needle Aspiration Biopsy

Thyroid Imaging

Thyroid with disorders

*Images taken from the internet*
Thyroid Imaging

Ultrasound

Radiography

Scintiscanning

CT Scan

MRI

*Images taken from: [www.thyroidimaging.com](http://www.thyroidimaging.com)*
Problem Statement

Accurate volume estimation of the thyroid gland using 2D Ultrasound Image / Image Sequences

Objectives:
1. Segmentation of thyroid gland and nodules for volume estimation
2. To develop a mathematical model for accurate estimation of thyroid gland volume.
Importance of Thyroid Volume Estimates

• Required for differential diagnosis
  • Normal gland volume 5-20ml depending age, gender etc..
• Required for therapy using radioiodine $^{131}$I [1]
  • Dosage calculation for treatment [1]
    \[ D = V \times \left[ \frac{100}{U} \right] \times C \]
    Where, \(D = ^{131}I\) dosage (MBq), \(V =\) Thyroid volume (ml), \(U = 24\text{hr thyroidal} ^{131}I\) uptake(%) and \(C\) is a constant

Methods to Estimate Thyroid Volume

- Modality based methods
  - Ellipsoid Method
  - Planimetry Method
  - Cavaliari Method
- Anthropometric Methods
- Computer Aided Methods
Ellipsoid Method

- Thyroid modeled as an ellipse

  - $V = \frac{\pi}{6} \cdot \text{height} \cdot \text{width} \cdot \text{length}$ [2-4]
  
  - $V = 1.24101 \cdot \frac{\pi}{6} \cdot \text{height} \cdot \text{width} \cdot \text{length} + 3.6627$ [5]


Planimetry Method

- \( V_p = \frac{\pi}{6} \times D_l \times 4 \frac{A_l}{\pi \times D_l} \times 4 \frac{A_t}{\pi \times D_t} \) \[6\]

where, \( D_l \) and \( D_t \) are the maximum depth in the longitudinal and transverse sections of the scan, \( A_l \) and \( A_t \) are crosssectional areas in the longitudinal and

- Used frequently with 3D imaging modalities like CT/MRI/3D Ultrasound

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Cavaliari Method

- Also known as point counting method [13]:

\[ V(PC) = T \times \left[ \frac{SU \times d}{SL} \right]^2 \times \Sigma P \]

Where \( SU \) and \( SL \) are scaling parameters, \( P \) is the number of points hitting the test grid and \( T \) is the slice thickness.

Anthropometric methods

- Metrics used [14]:
  - age
  - Body Surface Area (BSA)
  - \( \log(V) = 0.6089 + 0.832 \times BSA + 0.0403 \times age \)
  - \( \log(V) = 1.5988 + 0.7965 \times BSA - 0.1755 \times gender \)
    where \( gender = 0 \) for male and 1 for female
  - All constants obtained by statistical models built using software like IBM SPSS etc.

Computer Aided Methods

• [11] and [12] are the only papers that address the issue of Automatic Thyroid Segmentation and Volume estimation.

• Segmentation Results in [11]:
  • Volume estimation done using a new scheme that makes use of Particle swarm optimization
  • **Drawback**: Uses information obtained from CT scans to determine volume of US image

• Volume Segmentation Results in [12]:
  • **Drawback**: Uses biased ellipsoid model


Drawbacks of Existing methods

• All volume estimates are lower than the actual volume
• Ellipsoid Method is biased [1-4,7]
  • Doctors want new mathematical formulation of volume measurement – NONE FOUND SO FAR!
• Volume calculation inaccurate when a nodule(s) is present [1-4,7]
• Volumes are mostly manually determined and have a high inter-observer variance.

Proposed scheme

- Use 2D of ultrasound images for volume estimation

Preprocessing for artifact removal

Thyroid gland segmentation

Volume estimation

Validation
Preprocessing for Artifact Removal

- Manually Induced artifacts in Ultrasound Images:
  - Nodule markings by radiologists
  - Gland description
  - Machine induced markings
- 150 out of 190 images had artifacts
- Application of POC based methods [8-10].

Artifact Removal - Results

Before artifact removal

After artifact removal

Qualitative Analysis

- Restored image PSNR ~ 40dB
- Algorithm converges within 3 iterations

<table>
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<tr>
<th>Case Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>Average PSNR</td>
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<td>38.94</td>
<td>39.62</td>
<td>39.67</td>
<td>39.02</td>
<td>40.33</td>
<td>40.11</td>
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**TABLE I**

**RESTORATION QUALITY ANALYSIS**

(a) Input  (b) Output

Convergence of POCS algorithm
Segmentation

- Novelty:
  - Developed based purely on tissue echogenicity
  - Fully Unsupervised utilizing the state of the art automatic cluster estimation techniques
  - Speckle property of the image treated as a feature instead of noise

Segmentation - Results

(a) Input  (b) Fully labelled image  (c) Edge Map

Segmentation Accuracy

- Accurate to a tune of 90%
- Consistent cluster estimation up to very large thresholds

<table>
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<th>Tissue</th>
<th>Hyper (%)</th>
<th>Hypo (%)</th>
<th>Iso (%)</th>
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<tr>
<td>Thyroid</td>
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<td>9.09</td>
<td>9.09</td>
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<tr>
<td>Muscle</td>
<td>9.09</td>
<td>54.54</td>
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<tr>
<td>Carotid</td>
<td>9.09</td>
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Stability of algorithm
Future work

• Pre-process for image based artifacts like Shadow and Enhancement artifacts
• Upgrade the segmentation algorithm
  • Use of cluster validity schemes
  • Active Contours to aid in segmentation
• Segment the thyroid gland from the image
• Developing model for volume estimation
• Thyroid Volume Calculation
• Validating the workflow
Questions??