Algorithmic Hyoid Tracking and C2-C4 Length Measurement on Artificial Intelligence Predicted Segmentations

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Introduction

- In-depth analysis of videofluoroscopic swallow studies (VFS) is time consuming for the reasons listed below:
  - Identification of specific events through frame-by-frame advancement and review
  - Manual determination of features for measurements
  - Translation of information into clinically meaningful data
  - Use of 3rd party software for measurements or data recording
- The overall purpose of this work is to develop and utilize AI to support VFS analysis. This work focuses on specific structures that will be used to derive clinical metrics. This work shows the efficacy of using generalized algorithms for automatic measure determination.

Methods

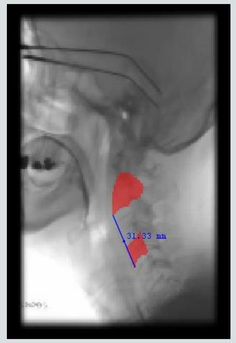


Figure 1: An example of manually measuring the C2-C4 length on ITK-SNAP.

Dataset

- All videos were cropped to remove shielded edges and motion frames not related to the swallow, recorded at 30 fps, and had various PAS scores
- C2-C4 lengths were measured on 21 videos and the hyoid was tracked on 10

Measurements

- **Manual**
  - C2-C4 length was measured on the rest frame in pixels using ITK – SNAP (Figure 1)
  - Hyoid was tracked by placing a point on the most anterior inferior corner on each frame
- **Algorithm**
  - C2-C4 length was determined using Canny edge detection to identify relevant points
  - Hyoid tracked using Canny edge detection for the most anterior inferior corner and center of mass

Results

Table 1: Hyoid tracking using the anterior inferior corner

Anterior Inferior Corner	Mean Average Tracking Error	Average Standard Deviation	Max Average Pixel Error	Min Average Pixel Error
Manual – Ground Truth	3.22	2.21	9.23	1.45
Manual – Predicted	4.36	3.84	14.34	1.72
Ground Truth – Predicted	5.55	4.01	15.81	2.56

Table 2: Hyoid tracking using the center of mass

Center of Mass	Mean Average Tracking Error	Average Standard Deviation	Max Average Pixel Error	Min Average Pixel Error
Manual – Ground Truth	2.13	0.79	3.15	1.01
Manual – Predicted	2.66	2.07	7.97	0.69
Ground Truth – Predicted	1.59	1.71	6.16	0.6

Table 3: C2-C4 length comparisons

C2 – C4 Length	Average Percent Error	Average Standard Deviation
Manual – Ground Truth	-3.22	3.58
Manual – Predicted	3.46	3.90
Ground Truth – Predicted	-.04	4.88

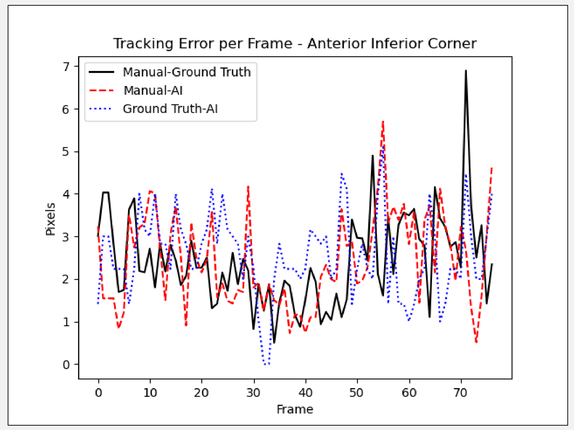
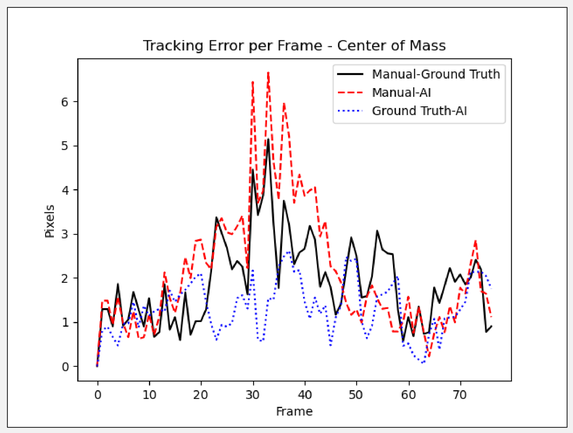


Figure 2: Frame by frame tracking error using the anterior inferior corner of the hyoid. Comparisons shown between the manual, ground truth, and AI predicted segment. Coordinates are not normalized to the position of the starting frame.

Figure 3: Frame by frame tracking error using the center of mass of the hyoid. Comparisons shown between the manual, ground truth, and AI predicted segment. Coordinates are normalized to the position of the starting frame.



Conclusion

- Development of generalized algorithms to automate metric determination during VFS analysis is necessary
- C2-C4 length measurements with a generalized algorithm are comparable to manual measurements (Table 3)
- Using the anterior inferior corner of the hyoid can result in accurate tracking on AI predicted segments (Figures 2 and 3)
  - Using the center of mass provides lower tracking error
  - Occlusion of the hyoid leads to inaccurate center of mass determination during pharyngeal phase

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DRS Dysphagia Research Society
Advancing the Science of Swallowing