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Deep Learning for Parotid Tumor Segmentation and Screening

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Clinical significance

- Parotid tumors represent over 70% of all salivary gland masses
- Automated accurate segmentation of parotid tumors…
  - Advances computational image analysis, radiomics, machine learning workflows
  - Serves as a valuable diagnostic aid
    - Especially in busy clinical practices

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Workflow incorporating AI-based detection algorithm

Healthcare Data

Algorithm ingests CT scans from worklist in clinical setting

A.I. Analysis

Cloud based AI algorithms automatically detect, measure and predict disease, highlighting positive findings

Trigger Action

Application notifies all appropriate healthcare providers of findings, thereby expediting clinical care coordination and mobilizing healthcare providers

Enable Therapy

Prompt, coordinated medical intervention and improved patient health outcomes

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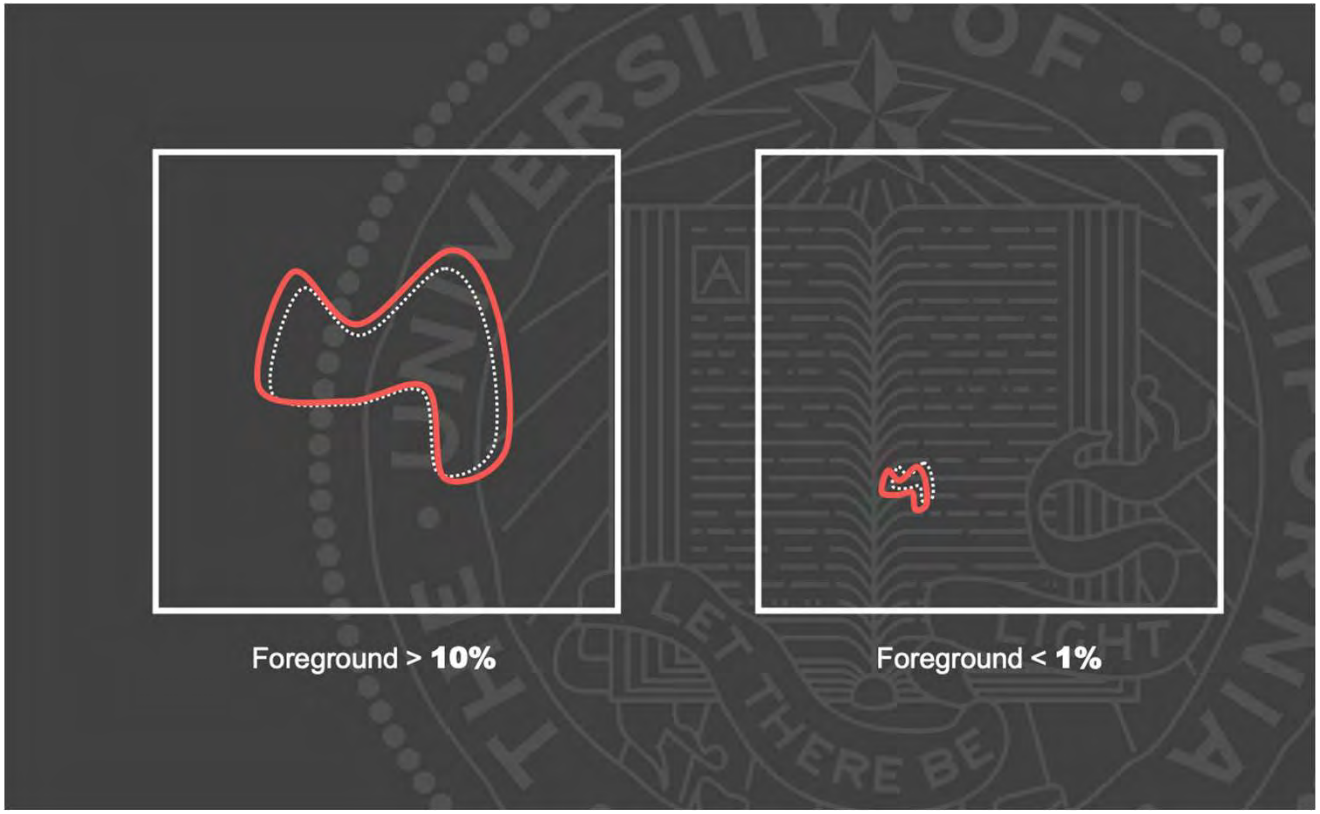
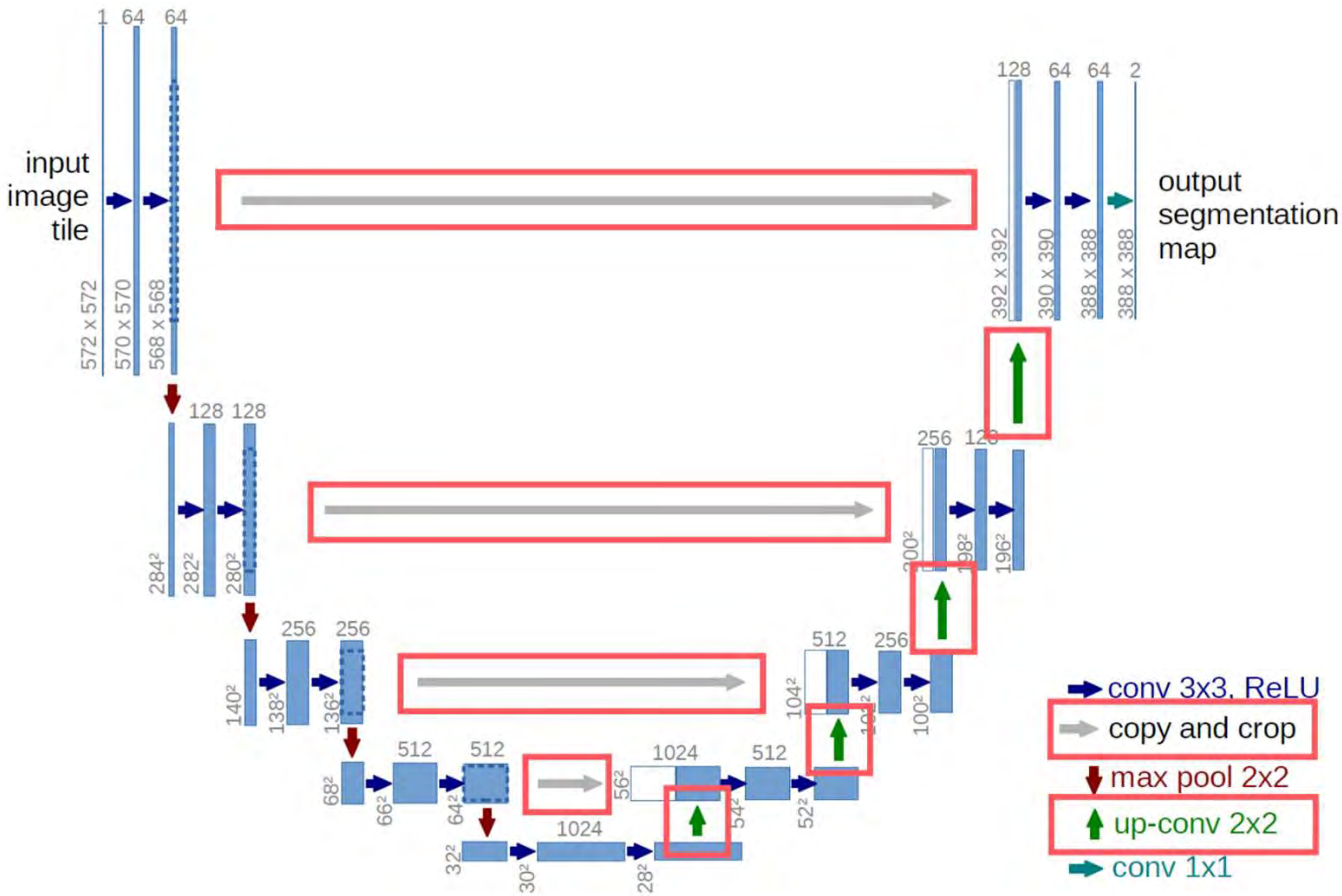
Study methods

- Segmentation task: outlining the tumor
  - Correctly identifying the boundaries
- Screening task: binary identification
  - Tumor or no tumor anywhere in the scan
- CT scans visually inspected for the presence of a parotid mass > 10 mm
  - Histopathology used to verify diagnosis
- Ground truth 3D tumor masks generated for each patient
  - Gold standard: all annotations were performed by a CAQ-certified neuroradiologist
  - CT neck protocols and routine exams (including head CT) included to maximize algorithm generalizability
- Two serial 3D deep learning algorithms were developed.
  - Algorithm localizes the right/left parotid glands individually
  - Cropped volumes generated by the first algorithm are inputs into a 3D contracting-expanding (U-Net) segmentation model
  - 5-10% boost from deep supervision incorporated into a standard U-Net model
  - Both models implemented using an identical 3D network comprised of 15 convolutional layers and 578,089 parameters

Benefits of cropped volumes



Architectures: Fully-Convolutional



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Study results: positive cases only

- **201 patients** with parotid masses identified from two academic medical centers
    - (N=100 for first site, N=101 from second site)
- Median tumor volume of 4.62 cm^3
- Segmentation yielded a Dice score of **0.725**
    - (IQR 0.500-0.788; test on N=40 hold-out patients)
- Excellent test performance
    - **AUC: 0.956**
    - **Accuracy: 0.900**
    - **Sensitivity: 0.884**
    - **Specificity: 0.919**
    - **PPV: 0.927**
    - **NPV: 0.872**
- No significant differences in performance between different academic centers or imaging protocols ($p > 0.05$)

Segmentation: Dice score calculations

Dice coefficient

Estimate for degree of mask overlap

$$\frac{2\,|X \cap Y|}{|X| + |Y|}$$

DSC = 1.0 : perfect overlap

DSC = 0.0 : no overlap

Visualization of segmentation task

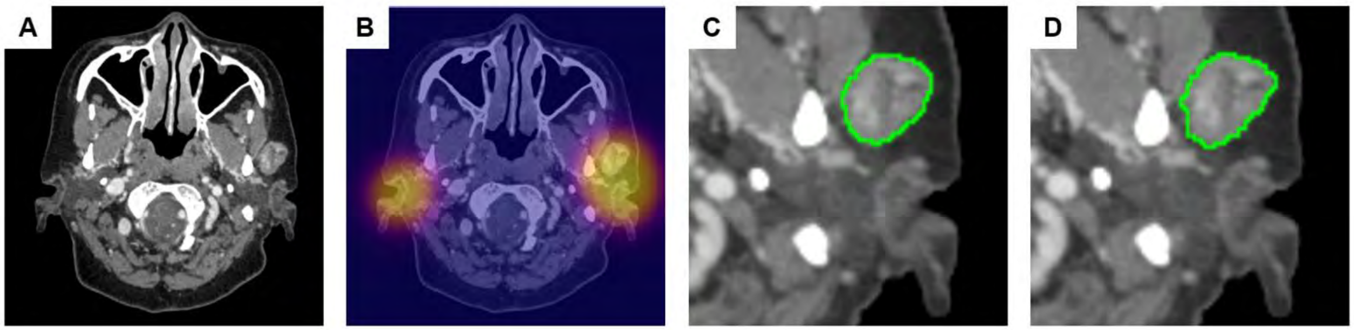

Figure 1. Overview of two-step deep learning algorithm for parotid mass detection and segmentation. (A) Original full resolution CT exam is used by initial deep learning localization algorithm to generate prediction heatmaps (B) isolating the right and left parotid glands. The initial localization algorithm outputs are used to generate cropped volumes of each individual parotid gland, after which a second segmentation algorithm is used to identify parotid masses. (C) Final algorithm output, and (D) corresponding ground-truth annotation show high consensus.

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Study results: incorporating negative cases

- 401 scans (201 original positive scans, 200 new negative scans)
- Parotid mass segmentation yielded a **Dice score of 0.65**
- Binary classification performance excellent
    - **Given Gamma=5, specificity > 95% and PPV > 90% with tumor threshold size of 500 pixels**
- Specificity and PPV are highest priority
    - Flag likely cases without causing notification fatigue
    - Incremental amount of definitive gain
- Deep learning model yielded 8 positive predictions not identified in the original radiology report

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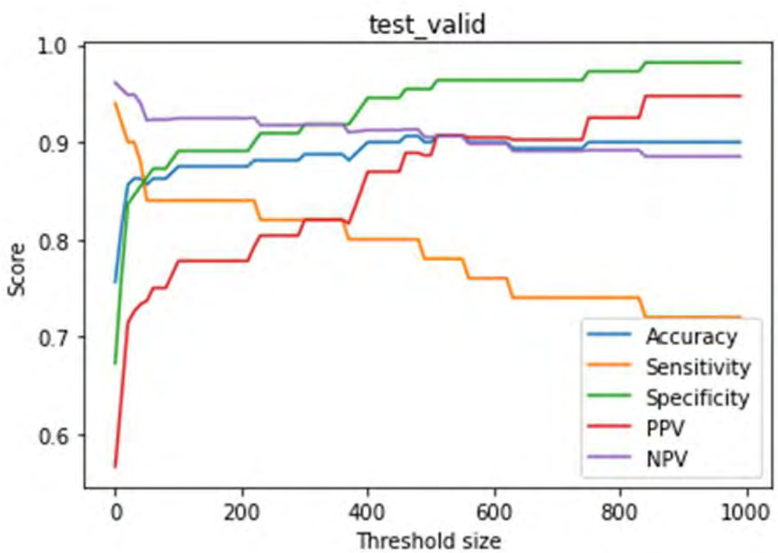
Segmentation task: varying gamma thresholds

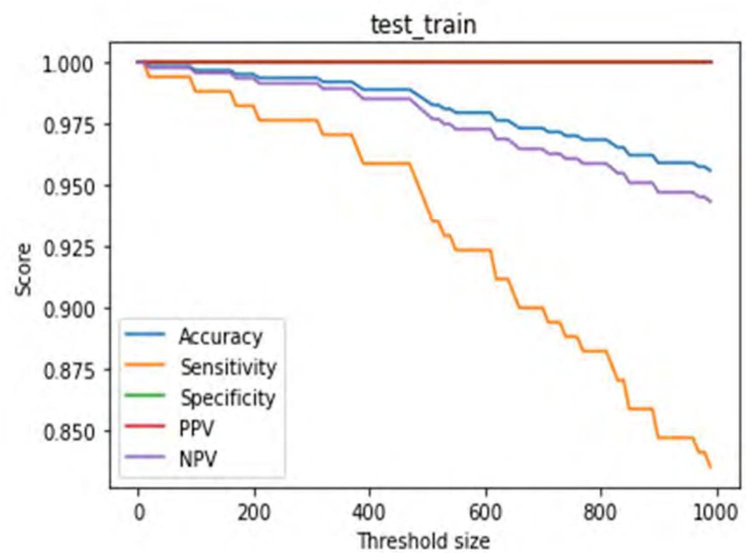
Gamma	1	2	3	4	5	6	7	8	9	10
Dice score	60.14%	63.78%	58.23%	64.63%	60.63%	64.51%	62.60%	61.02%	64.41%	65.54%

Gamma parameter is inverse of the radius of influence of samples selected by the model as support vectors.

Intuitively, this is how influential a single training example can be.

Binary classification: optimal performance with Gamma of 5





Next steps

- 10,000 head CTs accessible to us
- Continue to incorporate negative scans to improve algorithm performance
- Fine-tune parameters

Clinical takeaways

- The proposed automated algorithm can accurately:
  - detect incidental parotid masses on routine CT exam
  - segment parotid tumors for calculation of tumor volume (as well as facilitating radiomics and other machine learning workflows)

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Citations

- Journal: Shalini A. Amukotuwa, Matus Straka, Seena Dehkharghani, Roland Bammer. Fast automatic detection of large vessel occlusions on CT angiography. Stroke 2019; 50.12:3431-3438.
- Journal: McLouth Joel, Elstrott Sebastian, Chaibi Yasmina, Quenet Sarah, Chang Peter D., Chow Daniel S.,et al. Validation of a Deep Learning Tool in the Detection of Intracranial Hemorrhage and Large Vessel Occlusion. Frontiers in Neurology 2021; 12:655.
- Journal: Murray, Nick M and Unberath, Mathias and Hager, Gregory D and Hui, Ferdinand K. Artificial intelligence to diagnose ischemic stroke and identify large vessel occlusions: a systematic review. Journal of NeuroInterventional Surgery 2020; 12.2:156-164.