A Pipeline to Analyze Gigapixel-sized Digital Pathology Images for Tumor Detection

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Introduction
Whole slide imaging (WSI) has improved the identification and treatment planning for head and neck cancer. Deep learning has shown great potential for the analysis of digital pathology slides. In this work, we develop an effective pipeline for head and neck tumor detection using WSI. The proposed pipeline utilizes the state-of-the-art deep convolutional network architectures for image classification.

Hypothesis
Due to the high resolution of Whole Slide Images, computational imaging algorithms on them are computationally complex. A patch-based deep learning approach with aggregation for tumor prediction helps work around this challenge.

Methods
Our dataset consisted of 606 digitally scanned glass slides of surgical biopsy samples taken from head and neck regions from 25 patients. These slides were manually contoured by an expert pathologist resulting in the identification of 220 slides with tumors and 386 without tumors. The slides were split into three groups: training (60% of patients, 471 slides), validation (20% of patients, 50 slides), and test sets (20% of patients, 85 slides) such that slides from each patient were only present in one of these sets. We first applied a denoising step on slide images to remove artifacts. Then, in order to segment the tissues from the slide background, we used Otsu's thresholding followed by connected component-based contour detection. From these tissue contours, patches were extracted using a sliding window approach for non-tumor regions and random sampling for tumor areas. The patches were then used to fine-tune ResNet50 and EfficientNet-B2 models pre-trained on the ImageNet dataset. After acquiring patch-level classifications, the slide level classification into the tumor and the non-tumor class was done by thresholding the average of the top 100 patches with the highest prediction scores. Patients were diagnosed on the basis of at least one of the slides associated with them being detected with a tumor. Figure 1 illustrates the methodology.

Results
For the test data, we achieved an accuracy of 0.91 and an F1-score of 0.90 for patch classification and an accuracy of 0.80, and an F1 score of 0.90 for patient tumor detection (see Table 1). Figure 2 provides a visual summary of the model performance.

Conclusion
The proposed pipeline leads to accurate detection of tumors in head and neck WSI with the potential for assisting pathologists.

Statement of Impact
We propose an end-to-end whole slide imaging tumor detection system with high performance at both patch level and slide level that can be used to assist pathologists in a clinical setting.
Figures

Figure 1. Visualizing the end-to-end methodology for head and neck tumor detection in patients using a patch-based approach.

Figure 2. Visualizing the tumor detection model performance: (a) Original annotated WSI, (b) Binary ground truth annotation mask, (c) Binary classification output mask, (d) Stitched WSI patch image overlaid with classification mask, (e) Prediction probability heat map overlaid on stitched WSI patch image with associated color bar.
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<tr>
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<th>EfficientNet-B2</th>
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<th>ResNet-50</th>
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<tr>
<td></td>
<td>Accuracy</td>
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<td><strong>Patch Level</strong></td>
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<td><strong>Patient Level</strong></td>
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<td>0.6</td>
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*Table 1:* Performance measures of EfficientNet-B2 and ResNet50 based tumor detection models at the patch-level, whole slide level, and patient level.

**Keywords**
Squamous Cell Carcinoma; Digital Pathology; Whole Slide Imaging; Convolutional Neural Network; Transfer Learning; Tumor Detection