Using Deep Convolutional Neural Networks to Perform Cancer Segmentation on Head and Neck Histological Images

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Research Project Goals:

- Determine the cancer region (perform segmentation) on digital histological images of the head & neck.
- Implement a convolutional neural network (CNN) based on the U-Net architecture using the Keras deep learning software package.
- Train the CNN based on the U-Net architecture to perform cancer segmentation on histological images.

Research Project Overview:

Introduction/Problem Description

Cancer segmentation is a task that involves identifying the exact regions of cancer within an image of tissue. This is a time-consuming task that even trained physicians struggle with, which is why the use of deep learning models that can perform this task better than humans has become popular in medical imaging research. CNNs are biologically-inspired mathematical models that can learn to perform segmentation tasks given a large number of training examples.

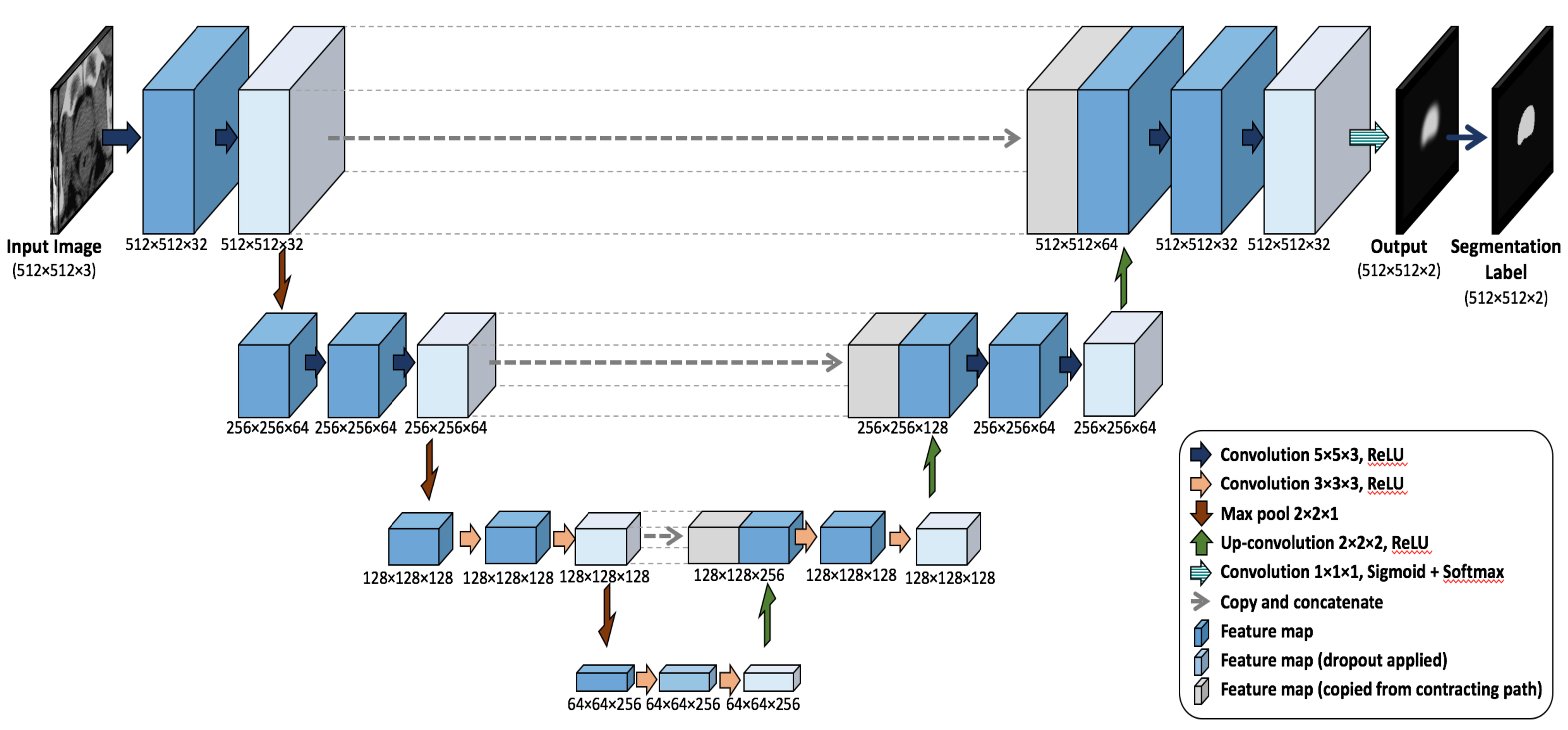
Methodology

For this segmentation problem, we trained a CNN based on the U-Net architecture (see Figure 1), first introduced in 2015, to perform cancer segmentation using a database of tissue samples obtained from previously consenting patients undergoing surgical cancer resection.

Each tissue sample was further split into slides that were then split into 512 x 512 pixel patches used for training, validating, and testing the performance of the neural network. Roughly 15,000 of these patches were used for training and 13,000 were used for validating the performance of the CNN.

The CNN architecture that we used for this research project was implemented using Keras, a high-level Python deep learning library, and trained on a high-performance computer with a NVIDIA GTX 1080Ti GPU for a period of about five hours. In addition, the CNN architecture for this project had five levels of convolutional blocks organized similar to the four-level U-Net architecture shown in Figure 1.

Figure 1: U-Net Architecture



Research Project Results:

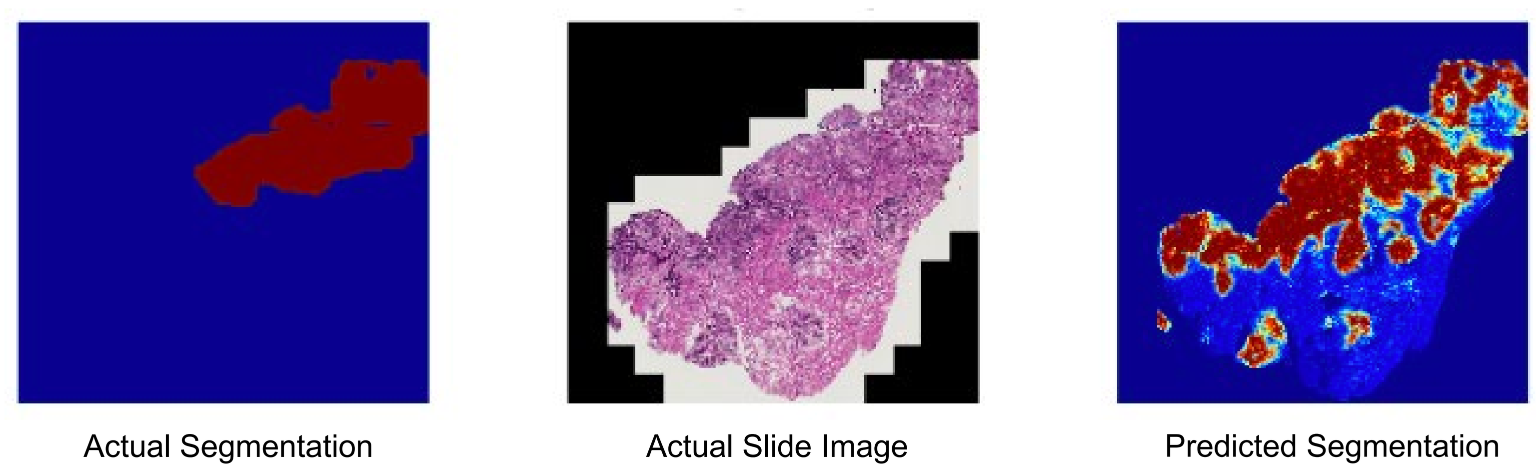
While training the CNN, the model's performance on the training and the validation data was periodically evaluated. The pixel-level accuracy, sensitivity, and specificity statistics were calculated separately for the training and validation groups and are listed in Table 1. The sensitivity, or true positive rate, represents the proportion of pixels in each image that were correctly identified as belonging to cancer cell regions. The specificity represents the proportion of pixels that were correctly identified as belonging to normal cell regions.

Table 1: Pixel-level performance statistics

Group	Accuracy	Sensitivity	Specificity
Training	75.2 %	86.3 %	60.7 %
Validation	74.7 %	79.4 %	71.1 %

In Figure 2 below, three images are presented. The image in the middle is an actual histology slide, while the images on the left and right represent the correct segmentation and the CNN's segmentation heat map where redder areas correspond to higher probabilities of cancer.

Figure 2: Visualization of segmentation performance.



Project Conclusions/Outcomes:

- Deep learning methods are able to detect cancer regions on digital histological images of the head and neck.
- By training a CNN based on the U-Net architecture to perform segmentation on histologic images, we were able to demonstrate that U-Net can be applied to a variety of medical image segmentation problems.
- Based on these results, model that we have trained has potential value in detecting cancer in histological slides.

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