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Department of Electrical and Computer Engineering

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Applications of Deep Learning to Cancer Detection in Digital Pathology

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Abstract:

Digital pathology has become a field of great interest in recent years because deep learning is enabling the development of a new generation of technology whose performance rivals that of pathologists using a manual review process involving analog microscopes. Deep learning systems can help reduce a pathologist's workload by providing decision support. The declining number of physicians pursuing careers in pathology necessitates the development of tools to increase efficiency and productivity. In this report, we discuss the essential components of deep learning systems that analyze histopathological images. We specifically focus on cancer detection from whole slide images (WSI).

Working with whole slide images, which are extremely high resolution (e.g., 100k × 100k pixels), is a significant computational challenge. A large database of these images, which is required to perform state-of-the-art deep learning, cannot fit into a computer's physical memory. Further, to provide useful diagnostic information for pathologists, these images must be segmented into small patches and analyzed patch by patch. This allows the system to identify local regions in each slide that supported the diagnosis but also risks a significant increase in the false alarm rate, which has important clinical implications. There are three fundamental challenges one faces in applying deep learning to digital pathology: (1) creation of a scientifically sound evaluation paradigm, (2) design of suitable pre- and postprocessing of the data to make it suitable for machine learning research, and (3) implementation of an architecture that can successfully classify small regions, or patches, of high-resolution images. We have selected three papers that address each one of these challenges.

The first paper, titled "Artificial Intelligence for Diagnosis and Gleason Grading of Prostate Cancer: The PANDA Challenge," presents a community-wide evaluation on data that included over 10,000 training images and over 1,000 evaluation images from five institutions. A total of 34,262 algorithms submitted by 1,290 developers were initially evaluated. Fifteen leading systems were shown to achieve a similar level of agreement with decisions made by a committee of pathologists and uropathologists (quadratically weighted kappa score of 0.828 at a 95% confidence interval). These algorithms performed similarly on blind evaluation data, supporting the hypothesis that differences between algorithms are small compared to learning how to make effective use of data.

The second paper, titled "A generalized deep learning framework for whole-slide image segmentation and analysis," discusses the segmentation process. The authors used an ensemble segmentation model that divides the image into a series of smaller patches and averages decisions that came from a pool of well-known segmentation algorithms. Four popular pathology databases were used to evaluate the approach. The proposed algorithm achieved a kappa score of 0.91 on

the CAMELYON17 test set (N=500) and a Dice similar coefficient (DSC) of 0.78 on the DigestPath test set (N=212). The combination of a kappa score above 0.8 and a DSC above 0.7 indicates strong agreement.

The third paper, titled “Contextual Transformer Networks for Visual Recognition,” (COTNet) introduces a robust model with low complexity that uses a transformer-like approach that integrates convolutional and attention mechanisms. The authors evaluated their approach on object detection, semantic segmentation, and instance segmentation, and showed that their approach reduced complexity and achieved better performance than contemporary approaches based on deep convolutional networks with residual interconnections. For example, COTNet achieved a top-1 accuracy of 80%, which was 1.5% absolute higher than ResNet-101, while reducing complexity by 1.8 GFLOPS and 6.3M parameters.

Since a cancer diagnosis is a life-changing event, any clinical system must have a low false alarm rate. This necessitates a deep learning system that can robustly segment data. In this report, we have introduced an experimental paradigm and some associated algorithms that offer the potential for automating the diagnosis process, thereby allowing pathologists to spend time on the most significant images. These algorithms can provide valuable decision support for pathologists.

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