ECS 174 Project Proposal

Members: Jonathan Levitsky, Sai Chamarty, Sambhav Agarwal
Date: November 4, 2025

I. Problem Statement

In Biomedical imaging, segmentation is essential to identify which parts of the microscopic image belong to cells and which parts belong to the background. This step is essential in biomedical engineering, as it is essential for application is tracking cells, measuring disease progressions, or even guiding robotic surgery, where each pixel matters.

Before deep-learning based convolution methods were developed, researchers detected edges and segmented through scanning over small window over images to complete segmentation. This process was proven slow, inefficient, and repetitive because it lacked greater detail and had a small window. It struggled to capture more context, and failed where edges were blurry or the lighting conditions were poor.

The paper that we are studying introduces a U-Net concept, which processes an image once rather than processing it piece by piece. It ensures that biomedical segmentation is quicker and easier, making it more practical for research and clinical tasks.

II. Motivation: Why is it important?

The 2015 U-Net paper (https://arxiv.org/abs/1505.04597) made a significant contribution in the field of image segmentation on small datasets. However, it was limited by a small dataset and it relied heavily on gradient descent, without using the optimization and regularization tools that are common today. We believe however that the model architecture they proposed and created could be improved using different ML techniques (optimizers, dropout, etc.) that weren't used in the paper at the time.

We understand that there are papers that exist already that build on U-Net, with architectures like U-Net++ and Attention U-net, however they adjust the underlying architecture of U-Net, while we hope to see improvement of the model, just from applying hyperparameter adjustments.

Our motivation is to implement more modern improvements, such as batch normalization or learning-rate scheduling, and improve the architecture's performance. We also want to test and optimize the U-Net Paper for larger data sets, and ensure that the data scaling improves accuracy.

By treating the U-Net paper as our benchmark, our goal is to show that we can improve the performance through updated training methods and data scaling, while keeping the same architecture framework.

III. Dataset

We will evaluate U-Net on modified biomedical image datasets to study how data size and resolution affect the performance on pixel segmentation. We will start with the ISBI Cell Tracking Challenge dataset (used in the original paper), allowing us to replicate the baseline under small data conditions. We will then test on a larger dataset, such as the 2018 Data Science Bowl or BBBC, to examine the generalized performance of the model. We can upscale ISBI images to increase pixel detail and downscale larger datasets to analyze the effect of modified resolution of images. This setup enables us to systematically compare how dataset size, image resolution, and modern training techniques (e.g., batch normalization, dropout, and advanced optimizers) influence segmentation quality over U-net.

Data Science Bowl 2018 Dataset: 2018 Data Science Bowl | Kaggle

BBBC Dataset: Image Sets | Broad Bioimage Benchmark Collection

ISBI Challenge Dataset: ISBI Challenge Dataset

IV. Method

We will implement the U-Net architecture from scratch by closely following the network design described in the original 2015 paper, ensuring that our baseline model matches the authors' specifications. Once the base model is established, we will introduce modern training improvements, such as batch normalization, dropout, weight decay, and advanced optimizers (e.g Adam or RMSProp), which will help us evaluate their impact on performance. We will also apply data scaling techniques, such as varying input image resolutions and dataset sizes to study how these factors influence segmentation accuracy. Finally, we will analyze the results using both the original ISBI dataset and a larger dataset (e.g., Data Science Bowl 2018 or BBBC) to determine whether these updates enable U-Net to achieve better segmentation quality and better performance without altering its core architecture.