Comparative Study of Deep Learning Models for the Segmentation of Large Intestine from the Computed Tomography Colonography Images

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Abstract
Traditionally, methods such as thresholding, region expanding, and conventional convolutional neural networks (CNNs) have been used for the segmentation of large intestine images. These techniques frequently have trouble detecting complicated diseases like inflammation or polyps, as well as variations in colon morphology and image quality. The inherent difficulties of dealing with low contrast, irregular boundaries, and noisy medical images often restricted the accuracy of segmentation. In this project, we are using deep learning architectures, namely UNet and Mask R-CNN, for precise large intestine segmentation from CT colonography (CTC) images is examined in this work. After that, research is conducted and used to evaluate how well these deep learning models perform based on their dice score. The findings offer important new information about the best DL models for large intestine segmentation in CTC, which can also help with large intestine related disease diagnosis also.

Keywords: CTC, DL, Large Intestine Segmentation, UNet, Mask R-CNN

1. INTRODUCTION

Virtual colonoscopy, or computed tomography colonography (CTC), has become a crucial easy screening method for colorectal cancer, one of the main causes of cancer-related deaths globally. Early studies concentrated on creating methods for using air to expand the colon and creating 3D images from CT scans. The potential for "virtual endoscopy" of the large intestine was investigated by important pioneers. In 1994, the United States produced the first report on CT. The speed and quality of CTC imaging were greatly enhanced by the invention of multi-slice CT (MSCT) technology. Faster high-resolution 3D image acquisition made possible by MSCT scanners improved diagnostic accuracy by lowering motion artifacts. The number of detector rows rose as CT technology developed, producing images with even greater resolution and quicker scan periods. The accuracy of CTC for colorectal cancer screening was confirmed by extensive clinical trials. As a less intrusive option to traditional colonoscopy, CTC has steadily gained popularity, especially among people who cannot or do not want to have the traditional procedure done. For people who have a high risk of colorectal cancer or who have trouble having a standard colonoscopy, it can be a useful screening tool. CT scans, which are used in CTC, expose patients to ionizing radiation. Nonetheless, the radiation dosage is typically regarded as minimal. The lumen, walls, and surrounding tissues of the colon can all be seen in great detail in CTC pictures. Accurately defining the colon's borders requires this knowledge.

They are created from cross-sectional pictures of the abdomen and pelvis obtained from CT scans. Convolutional Neural Networks (CNNs) have produced state-of-the-art results in the segmentation of anatomical structures from medical pictures, especially encoder-decoder architectures like U-Net. The difficult task of large intestine segmentation from CTC pictures is a good fit for DL models since they can directly learn complicated characteristics from data. The purpose of this comparison study is to assess how well different DL models segment the large intestine from CTC pictures. To determine the best strategy for this particular application, we will examine the effectiveness of several network designs, loss functions, and training techniques. The goal is to contribute to the creation of strong and dependable automatic segmentation tools for CTC by offering a thorough analysis of each model's advantages and disadvantages. There are numerous important advantages to the precise and effective segmentation of the large intestine from CTC pictures, including: Accurate segmentation makes it easier to find and describe polyps, which raises the CAD systems' sensitivity and specificity. Radiologists may read CTC pictures faster thanks to automated segmentation, which boosts productivity and lessens workload. By using segmentation, quantitative features like volume, surface area, and form may be extracted, which can help with polyp characterisation and risk assessment. By lowering inter-observer variability, automated segmentation guarantees consistent and repeatable outcomes. The clinical workflow of CTC can be greatly enhanced by the development of reliable DL-based segmentation techniques, which could result in early CRC identification and better patient outcomes. Patients and medical professionals will ultimately benefit from this research's contribution to the development of automated image analysis tools in medical imaging. Additionally, precise segmentation makes it easier to perform quantitative analysis of the colon, allowing parameters like volume, surface area, and shape to be extracted. These properties can help with polyp characterization and risk stratification. Additionally, segmentation makes it possible to create three-dimensional (3D) representations of the colon, which enhance comprehension of its anatomical structure and facilitate surgical planning. The intent of this comparison study is to present a thorough assessment of different DL models for large intestine segmentation from CTC pictures. This research helps create robust and dependable automated segmentation tools that can be easily included into clinical workflows by determining the best models and training techniques.

2. Related Work

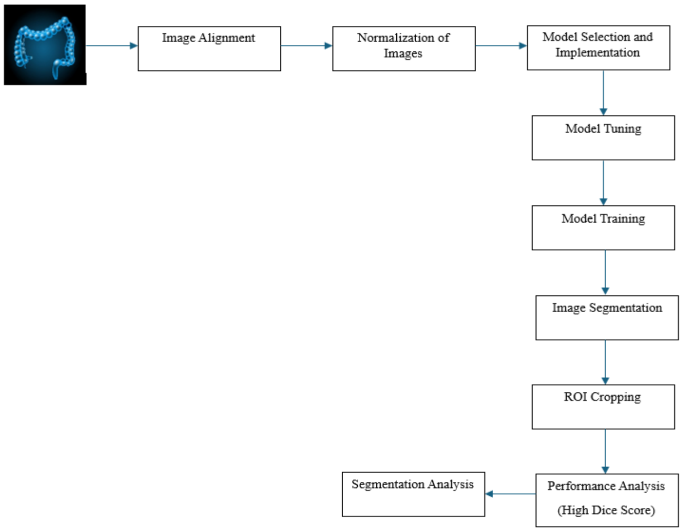
[1] Phillip Wesp, et.al, 2022, says that, “Deep Learning in CT colonography: differentiating premalignant from benign colorectal polyps”. In this paper, polyps of all size categories and morphologies were manually segmented on supine and prone CT colonography images and classified as premalignant or benign according to histopathology. SEG and noSEG were trained on 3D CT colonography images to predict polyp classes, and model SEG was additionally trained with polyp segmentation tasks. The deep learning enabled the differentiation of premalignant from benign colorectal polyps detected with CT colonography and visualizing the image regions important for predictions. The approach didn't require polyp segmentation and has the potential to facilitate the identification of high-risk polyps. [2] Elisson da Si, et.al,2022, explains that, “A Comparative study of Deep learning models for Dental Segmentation in Panoramic Radiograph”. In this paper, a comparative study is carried on U-Net, DCU-Net, DoubleU-Net and Nano-Net are prominent in medical literature on segmentation and the, the evaluation of results with the current state of the art of dental segmentation in panoramic radiograph. DoubleU-Net model presents the best accuracy of about 96.591% and 92.886%. The results obtained in this work are satisfactory and then present the path for a better and more effective dental segmentation process. [3] Mai Tharwat, et.al, 2022, describes that, “Colon cancer diagnosis based on Machine Learning and Deep Learning Techniques: Modalities and Analysis Techniques”. Here, a comprehensive study is done on diagnosis of colon cancer. A comprehensive review is provided on the current studies of colon cancer, is classified into ML and DL techniques and then, their strengths and limitations are identified. These techniques provide an extensive support for identifying the early stages of cancer that lead to early treatment of cancer. These methods help

to prevent colorectal cancer from progressing through the removal of premalignant polyps, which can be achieved using screening tests to make easier diagnosis of diseases. After diagnosis, the next stage is identifying the stage of cancer, an appropriate treatment can be provided based on the stage of disease. In future, there is a need to implement a comparative study of ML and DL techniques by using datasets and predefined evaluation metrics. [4] Praneeth Nemani, et.al ,2022, explains that," Medical Image Segmentation using LeViT-UNet++: A Case Study on GI Tract Data". In this paper, Gastro-intestinal cancer (GT) is considered a fatal malignant condition of the organs in GI track. Traditional segmentation depends on handcrafted features and are computationally expensive and inefficient. The CNN transformer architecture is introduced to segment the different organs from an image. This paper addresses the problem from computationally efficiency perspective. Segmentation on different organs is performed using MRI scan images and using a hybrid CNN-Transformer based architecture. To improve the model's performance, the architecture can be modified and improved in further domains. [5] Rick Van De Zedde, et.al, says that, to address this variation, deep learning techniques are suggested. Additionally, a multi-perspective method is used to incorporate data from the two-dimensional (2D) pictures into a three-dimensional (3D) point-cloud model of the plant. For instance and semantic segmentation on the 2D pictures, a masked R-CNN (region-based convolutional neural network) and a fully convolutional network (FCN) were employed. The 3D point cloud was then segmented by combining the several perspectives. On tomato seedling plants, the effectiveness of the 2D and multi-view techniques was assessed. Their findings demonstrate that 3D information integration performs better than 2D since 2D inaccuracies are not persistent across various views and may thus be corrected in 3D. [6] Ying Yu, Chunping , 2023 says that ,"Techniques and Challenges of Image Segmentation: A Review" states that Three crucial phases of image segmentation—classic segmentation, collaborative segmentation, and semantic segmentation—are primarily examined in accordance with segmentation principles and image data characteristics. They analyze and describe the benefits and drawbacks of various segmentation models, go over their application, and go into detail about the primary algorithms and crucial strategies in each step. Lastly, we examine the primary obstacles and advancements in the image segmentation technique. [7] Nida M. Zaitouna, et.al,2015, describes that," Survey on Image Segmentation Techniques ", explained that, a traditional topic in image processing, image segmentation is also a hotspot and area of concentration for image processing methods. For picture segmentation, a number of general-purpose algorithms and methods have been developed. Since the image segmentation problem lacks a universal solution, these methods frequently need to be paired with domain knowledge need to successfully address a problem domain's image segmentation issue. A comparison of the fundamental Block-Based image segmentation methods is presented in this paper. [8] Arpit Mohankar, et.al,2024, explains that, "Medical Image Segmentation", focuses on the survey highlights the increasing prevalence of convolutional neural networks (CNNs) and their variations, such as Fully Convolutional Networks (FCNs) and U-Net, which have demonstrated exceptional efficacy in managing intricate medical imaging difficulties. The study also covers hybrid approaches that enhance segmentation tasks' accuracy and robustness by fusing traditional methods with artificial intelligence. Important issues including boundary delineation, class imbalance, and computing efficiency are also emphasized. Prospective approaches to overcoming the present constraints in medical picture segmentation are examined, including the incorporation of multi-modal data and developments in self-supervised learning. [9] Rakesh Pandit, et.al,2023, says that," Satellite Image Segmentation Using Neural Networks: A Comprehensive Review", Neural networks have become extremely effective techniques for satellite image processing in recent years, providing dependable and strong segmentation results. This academic article offers a thorough analysis of the most recent methods for segmenting satellite images using neural networks. Different neural network topologies, preprocessing methods, loss functions, and evaluation metrics used in satellite image segmentation are covered in the study. It also looks at the difficulties and potential paths in this field.[10]K Srinivas Rao, et.al,2014, describes that, "Image Segmentation for Animal Images using Finite Mixture of Pearson type VI

Distribution", The EM approach for estimating the model's parameters and maximum likelihood for the picture component under the Bayesian framework is used to construct the image segmentation algorithm. The model's initial estimations are necessary for the EM algorithm to converge quickly. K-means and the Hierarchical Clustering algorithm are used to divide the entire image into K image regions, and the moment technique of estimates is used to determine the parameters. An experiment using a collection of animal photos and the computation of image quality metrics including PRI, GCE, and VOI is used to examine the performance of the suggested approach.

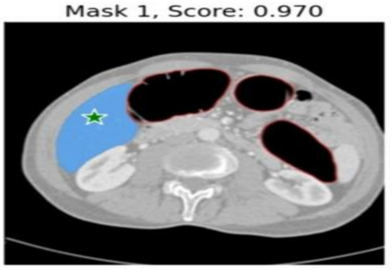
3. Research Methods used

Figure 1: Workflow of Project



We have used large intestine CTC 2D images dataset, for this project. The similar pixel intensities were used to align the images. The dataset was pre-processed by resizing and normalizing the images. In order to reduce complexity in dataset, without obfuscating crucial boundaries, appropriate filtering techniques were employed. Deep learning models such as UNet and Mask RCNN were used for segmentation. After training both the models, we got dice score for UNet with 0.97 and for RCNN with 0.83. The segmentation job was a good fit for the selected model, which was probably U-NeT. The filter sizes and depth of the network were tuned. The projected segmentation and the ground truth have a very strong overlap, as indicated by the unusually high dice score of 0.97. The model was focused on the appropriate area by precisely cropping the ROI that included the intestine. In essence, the model's segmentations were nearly exact matches to the radiologists' drawings, as indicated by the absurdly high Dice score of 0.97. This occurred because of our excellent CTC scans, the radiologists' extreme precision, our excellent picture cleanup, the model's flawless training, and, when used, the excellent post-processing. To receive a score so high, all those things had to go perfectly. While Mask R-CNN could provide us with more information, U-Net was simpler to use. Determining which tool is best for the job was a useful exercise.

Figure 2: Dice score of masked image using UNet



A score of 0.97 indicates a high level of agreement between the predicted segmentation mask and the ground truth mask using Mask-RCNN. It means that 97% of the predicted mask overlaps or agrees with the ground truth mask, which suggests good performance in the segmentation task.

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