Chapter 4
Advanced Polyp Segmentation Using U-Net Architecture: A Review

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ABSTRACT

Early detection of polyps in colonoscopy images is crucial for preventing and treating colorectal cancer, a leading cause of cancer deaths worldwide. Accurate segmentation, which isolates polyps within the image, is essential for this detection process. This paper reviews the application of deep learning, specifically the U-Net architecture, for polyp segmentation. Thanks to its encoder-decoder architecture, U-Net can efficiently collect contextual information while maintaining spatial features, making it suitable for such use. Benchmark dataset evaluation confirms the effectiveness of U-Net models in accurately segmenting polyps within colonoscopy images. The presented technique is a viable option for computer-aided polyp detection, with the potential to improve early cancer diagnosis.

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I. INTRODUCTION

Medical imaging has become an essential tool in modern healthcare. Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans provide highly detailed views of internal organs and structures, aiding in accurate diagnoses, treatment planning, and surgical guiding. However, because of their complex architecture and overlapping properties, deciphering these images can be challenging.

Medical image segmentation (Prasantha et al., 2010) emerges as an effective solution to this issue. It allows for the identification of Regions of Interest (ROIs) within various 2D/3D imaging modalities, like MRI, CT or X-Rays. These ROIs could include organs, tissues, or even specific illnesses like cancer. Isolating these zones enables medical staff to take more precise measurements, perform quantitative analyses, and extract important information for better clinical decision-making.

One critical use of medical image segmentation is in gastroenterology, notably in the analysis of colonoscopy images to locate polyps. Colonoscopy is important in early colorectal cancer (CRC) screening because it allows for visual examination of the colon's inner lining as well as the identification and removal of polyps, which are precancerous growths that can progress to cancer. However, reliable polyp diagnosis during a colonoscopy can be difficult due to differences in polyp size, shape, and color, as well as potential limits in human visual perception.

Focusing on deep learning, a powerful branch of AI, this study investigates its potential to overcome this obstacle. This review explores the potential of U-Net, a powerful deep learning network for semantic segmentation, in tackling this challenge. The review looks at how U-Net can be applied to segment polyps in colonoscopy images, potentially aiding in improved polyp detection and ultimately earlier diagnosis.

The U-Net (Ronneberger et al., 2015) architecture is very useful for this application because to its unique design. This architecture leverages an encoder-decoder structure. The encoder extracts contextual information from the input image, which the decoder then utilizes to generate a pixel-by-pixel segmentation map. This enables the U-Net to not only detect the existence of polyps, but also precisely define their borders.

The remainder of this paper is organized as follows. Section II summarizes the various datasets used in polyp segmentation and the evaluation metrics employed to analyze the performance of segmentation algorithms. Section III discusses the structure of the U-Net architecture. An overview of optimization methods for polyp segmentation is given in Section IV. Section V examines the deep learning approaches based on U-Net used in polyp segmentation. The concluding section (Section VI) summarizes the paper's key findings and highlights potential directions for future research in this field.