



Bachelor Project

Multiscale Brain MRI Segmentation with Deep Generative Models

Authors:

Simon Winther & Hjalte Bjoernstrup

University of Copenhagen

Faculty of Science, Department of Computer Science

Supervisor: Mostafa Mehdipour Ghazi

February 1, 2025



Contents

1	Introduction	2
----------	---------------------	----------

Introduction

Recent advances in medical image segmentation have been propelled by the synergy of UNet-based architectures [2, 8] and diffusion models [3, 5]. While traditional CNNs like UNet++ [8] addressed feature hierarchy limitations through nested skip connections, subsequent innovations such as UNet 3+ [2] expanded this framework with full-scale aggregation. These architectures laid critical foundations for handling anatomical complexity but faced persistent challenges in modeling ambiguity [4] and 3D consistency [1]. The advent of diffusion models has introduced paradigm-shifting approaches for uncertainty quantification. Concurrently, hybrid frameworks like MedSegDiff [6] and its transformer-enhanced variant [7] integrate diffusion steps directly into segmentation pipelines, achieving state-of-the-art performance on benchmark datasets. For volumetric data, [1] introduces diffusion-embedded 3D UNets, addressing memory constraints through adaptive spatiotemporal sampling.

References

- [1] Hu et al. Diff-unet: A diffusion embedded network for volumetric segmentation. *arXiv preprint*, 2024.
- [2] Huimin Huang, Lanfen Lin, Ruofeng Tong, Hongjie Hu, Qiaowei Zhang, Yutaro Iwamoto, Xianhua Han, Yen-Wei Chen, and Jian Wu. Unet 3+: A full-scale connected unet for medical image segmentation. *ICASSP*, pages 2508–2512, 2021.
- [3] Zengxin Liu, Caiwen Ma, Wenji She, and Meilin Xie. Biomedical image segmentation using denoising diffusion probabilistic models: A comprehensive review and analysis. *Applied Sciences*, 14(632), 2024.
- [4] Aimon Rahman, Jeya Maria Jose Valanarasu, Ilker Hacihaliloglu, and Vishal M. Patel. Ambiguous medical image segmentation using diffusion models. *arXiv preprint*, 2023.
- [5] Yaqing Shi, Abudukelimu Abulizi, Hao



- Wang, Ke Feng, Nihemaiti Abuduke- [7] Junde Wu, Wei Ji, Huazhu Fu, Min limu, Youli Su, and Halidanmu Xu, Yueming Jin, and Yanwu Xu. Abudukelimu. Diffusion models for Medsegdiff-v2: Diffusion-based medical image computing: A survey. *image segmentation with transformer. Tsinghua Science and Technology, arXiv preprint*, 2023.
- 30(1):357–383, 2025.
- [6] Junde Wu, Rao Fu, Huihui Fang, [8] Zongwei Zhou, Md Mahfuzur Rahman Siddiquee, Nima Tajbakhsh, and Jianming Liang. Unet++: Redesigning skip connections to exploit multi-scale features in image segmentation. *IEEE Transactions on Medical Imaging*, 39(6):1856–1867, 2020.
- [6] Junde Wu, Rao Fu, Huihui Fang, Yu Zhang, Yehui Yang, Haoyi Xiong, Huiying Liu, and Yanwu Xu. Medsegdiff: Medical image segmentation with diffusion probabilistic model. *arXiv preprint*, 2023.