A Comprehensive Survey of Mamba Architectures for Medical Image Analysis: Classification, Segmentation, Restoration and Beyond

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Mamba, a special case of the State Space Model, is gaining popularity as an alternative to template-based deep learning approaches in medical image analysis. While transformers are powerful architectures, they have drawbacks, including quadratic computational complexity and an inability to efficiently address long-range dependencies. This limitation affects the analysis of large and complex datasets in medical imaging, where there are many spatial and temporal relationships. In contrast, Mamba offers benefits that make it well-suited for medical image analysis. It has linear time complexity, which is a significant improvement over transformers. In sequence modeling tasks, computational complexity grows linearly with the length of the input sequence. Mamba processes longer sequences without attention mechanisms, enabling faster inference and requiring less memory. Mamba also demonstrates strong performance in merging multimodal data, improving diagnosis accuracy and patient outcomes. The paper's organization allows readers to appreciate Mamba's capabilities in medical imaging step by step. We begin with clear definitions of relevant concepts regarding SSMs and concept models, including S4, S5, and S6. We then explore Mamba architectures, including pure Mamba, U-Net variants, and hybrid models that combine Mamba with convolutional networks, transformers, and Graph Neural Networks. Subsequent sections cover Mamba optimizations, techniques such as weakly supervised and self-supervised learning, scanning mechanisms, and a detailed analysis of applications across various tasks. We provide an overview of available datasets and several experimental results regarding Mamba's efficacy in different domains. Furthermore, we detail the challenges and limitations of Mamba, along with other interesting aspects and possible future directions. The final subsection explains the importance of Mamba in medical imaging and provides an analysis and conclusions regarding its usage and enhancement measures. This review aims to demonstrate the transformative potential of Mamba in overcoming existing barriers within medical imaging while paving the way for innovative advancements in the field. A comprehensive list of Mamba architectures applied in medical field, reviewed in this work is available on Github§.

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§https://github.com/Madhavaprasath23/Awesome-Mamba-Papers-On-Medical-Domain

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Contents

Abstract 1
Contents 2
1 Introduction 3
2 Core Concepts of SSM 5
2.1 State Space Models 6
2.2 Structured State Space Sequence Models (S4) 6
2.3 Simplified State Space Layers for Sequence Modeling (S5) 7
2.4 Selective Structured State Space Models (S6) 7
3 Medical Image Analysis using Mamba 8
3.1 Mamba Architectures 8
3.1.1 Pure Mamba 9
3.1.2 Variants of U-Net 12
3.1.3 Hybrid Architectures 15
3.2 Scanning 18
3.3 Mamba Optimizations 23
3.3.1 Lightweight and Efficient 23
3.4 Techniques and Adaptations 25
3.4.1 Weakly Supervised Learning 25
3.4.2 Semi-Supervised Learning 25
3.4.3 Self Supervised Learning 25
3.4.4 Multimodal Learning 26
3.5 Applications in Various Medical Domains 28
3.5.1 Medical Image Segmentation 28
3.5.2 Medical Image Classification 34
3.5.3 Medical Image Restoration/ Reconstruction 36
3.5.4 Medical Image Registration 38
3.5.5 Miscellaneous 40
4 Datasets 43
5 Experiments and Results 45
5.1 Segmentation 45
5.2 Classification 47
5.3 Registration 47
6 Discussion 48
6.1 Limitations 48
6.2 Emerging Areas 48
7 Conclusion 50
7.1 Significance for the Field 50
7.2 Summary of Key Findings 50
7.3 Future Directions 50
References 51