DEEP LEARNING BASED U-NET VARIANTS FOR CARDIAC MRI SEGMENTATION

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DECLARATION

I declare that this is my own work and this Thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 2025/05/21

The supervisor should certify the Thesis with the following declaration.

The above candidate has carried out research for the Master of Science in Computer Science & Engineering Thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Prof. Dulani Meedeniya

Signature of the Supervisor: Date: 22/ 05/ 2025

DEDICATION

I dedicate this thesis report to the unwavering support and boundless love of my parents, whose encouragement and belief in my abilities have been the foundation of my academic journey. Their sacrifices and dedication to my education have shaped me into the person I am today.

To the University of Moratuwa, my academic home since my undergraduate years, I extend my gratitude for providing an environment that fosters intellectual growth and innovation. The knowledge and skills I have gained here have been instrumental in undertaking this research endeavor.

I express my deepest appreciation to my supervisor, Prof. Dulani Meedeniya, for her invaluable guidance, mentorship, and unwavering support throughout the research process. Her expertise and encouragement have been a guiding light, propelling me forward in my academic endeavors.

I extend heartfelt thanks to the hardworking Cardiologists and Radiologists whose dedication to patient care inspired this research. Their expertise and collaborative spirit have not only elevated the quality of this study, but also emphasized the importance of bridging the gap between medical practitioners and researchers in the pursuit of improved diagnostic tools and methodologies.

I am also grateful to the contributors of publicly available datasets, whose commitment to advancing research by sharing valuable resources has significantly contributed to the success of this research. Their generosity has broadened the scope of this study, enabling a more comprehensive analysis and understanding of cardiac MRI segmentation of ventricular structures and myocardium.

This work is dedicated to all those who have played a role, big or small, in shaping this academic endeavor. Your support and contributions have been instrumental in bringing this thesis to fruition.

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I would like to express my sincere gratitude to my supervisor, Prof. Dulani Meedeniya, whose unwavering support and guidance have been instrumental in the successful completion of this research. Her expertise, encouragement, and valuable insights have significantly contributed to the development and refinement of my research in the field of Cardiac MRI segmentation of ventricular structures and Myocardium.

I would like to express my sincere gratitude to Mr. Dharshana Muthtettugoda for his invaluable support in facilitating access to the High Performance Computing (HPC) server and for his continuous assistance in troubleshooting connectivity issues throughout the course of this research. I also extend my sincere gratitude to the Department of Computer Science and Engineering for granting me access to the HPC resources, which were crucial for the successful completion of my work.

I extend my heartfelt appreciation to the contributors of related studies, whose groundbreaking work has laid the foundation for my research. Their pioneering efforts have enriched my understanding and provided a robust framework for the exploration of cardiac MRI segmentation.

I am also grateful to those who generously made publicly available datasets, without which the empirical validation of my research would not have been possible. Their commitment to advancing scientific knowledge by sharing resources has been a vital aspect of my research journey.

I would like to acknowledge the invaluable feedback and support from my colleagues and peers. Their constructive criticisms, discussions, and encouragement have played a pivotal role in shaping the direction of my research and refining its methodologies.

Last but not least, I want to express my deepest gratitude to my parents for their unwavering support, understanding, and encouragement throughout this academic journey. Their love and encouragement have been a constant source of inspiration, motivating me to strive for excellence.

This thesis represents the culmination of the collective efforts and support from these individuals, and I am truly grateful for their contributions to the successful completion of this research project.

ABSTRACT

Accurate segmentation of ventricular structures and the myocardium from Cardiac Magnetic Resonance (CMR) images is essential for the diagnosis and management of cardiovascular diseases. This study presents a comprehensive approach to cardiac MRI segmentation by developing and evaluating six U-Net variants: Original U-Net, Residual U-Net, Attention U-Net, Feature Pyramid U-Net, Feedback Residual U-Net, and Transformer-Based U-Net, each incorporating architectural enhancements tailored to address specific challenges in segmenting complex cardiac anatomy. These architectures incorporate advanced enhancements such as deeper encoder levels, attention mechanisms, residual connections, multi-scale feature fusion, transformer modules, and feedback mechanisms. To improve segmentation robustness, a novel hybrid loss function, combining Dice Loss and Cross-Entropy Loss, was proposed to effectively manage class imbalance and improve segmentation precision. Among the evaluated models, the Feature Pyramid U-Net achieved the highest performance, with Dice coefficients of 0.9388 (Left Ventricle), 0.8759 (Right Ventricle), and 0.8426 (Myocardium), demonstrating its superior ability to capture multi-scale contextual information. To bridge the gap between research and clinical application, an interactive web application was developed and deployed, enabling real-time inference, visual inspection of annotated segmentations, and region-specific descriptions through a user-friendly interface. This work not only advances the design of deep learning architectures for medical image segmentation, but also demonstrates a practical pathway for integrating these models into clinical workflows.

Keywords: Cardiac MRI, Segmentation, U-Net

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
ACDC	Automated Cardiac Diagnosis Challenge
Atn-UN	Attention U-Net
CMR	Cardiac Magnetic Resonance
CMRI	Cardiac Magnetic Resonance Imaging
CNN	Convolutional Neural Network
DC	Dice Coefficient
DL	Deep Learning
ED	End Diastolic
ES	End Systolic
FCN	Fully Convolutional Neural Network
Feed-Res-UN	Feedback Residual U-Net
FP-UN	Feature Pyramid U-Net
FPB	Feature Pyramid Block
FPN	Feature Pyramid Network
GANs	Generative Adversarial Networks
GRU	Gated Recurrent Unit
JC	Jaccard Coefficient
LSTM	Long Short-Term Memory
LV	Left Ventricle
ML	Machine Learning
MLP	Multi-Layer Perceptron
MRI	Magnetic Resonance Imaging
MYO	Myocardium
O-UN	Original U-Net
Res-UN	Residual U-Net
RNN	Recurrent Neural Network
ROI	Region of Interest
RV	Right Ventricle
SSMs	Statistical Shape Models
w.r.t	with respect to

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