



Abstract of the Thesis



Name: THACKER SMIT MAHENDRABHAI

Enrollment No.: 219999913010

Faculty: Engineering

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Title of the Thesis: Deep Learning based Framework for Early Detection and Classification of CKD using Medical Imaging

Abstract

A worldwide public health crisis that is expanding, kidney illnesses, such as cysts, stones, and tumors, are a large burden. Chronic Kidney Disease (CKD) is impacting 10% of the world population and leads to just over 1.2 million deaths each year. Accurate, automated identification of kidney illnesses through the use of Computed Tomography (CT) images will contribute greatly to meeting the unreached priorities of healthcare professionals and provide an efficient input for earlier detection of illness than current manual interpretation processes can provide.

As a solution, this research presents a new framework of artificial intelligence, RenalViT, that is hierarchical and utilizes transformer-based deep learning to produce algorithms that automatically classify CT images of the kidney into four clinically relevant categories: Normal, Cyst, Stone, or Tumor. RenalViT uses multiple techniques including 16 x 16 patch tokenization, learnable positional embeddings, four transformer encoder blocks with 4 multi-head self-attention mechanisms, GELU activation functions in the 3 MLP sub-layers of the transformer encoder block, and an inverse frequency class weighting loss function, to mitigate class imbalance in the dataset used.



To ensure the strength of the results produced by RenalViT a systematic benchmark against 4 widely used convolutional neural network (CNN) architectures: VGG16, ResNet50, DenseNet121 and EfficientNetB3 was completed under the exact same experimental setting parameters on a publicly available CT Kidney Image Dataset containing 12,438 CT images. All models were trained using the identical pre-processing, augmentation, hyper-parameter configuration and evaluation protocols to allow for equitable and systematic automated comparison.

The results of this study demonstrate that RenalViT has performed superiorly in effectively classifying images when benchmarked against the aforementioned architectures. As a result, RenalViT represents a powerful tool that can be used to assist clinicians with the identification of kidney ailments at a higher level than they are currently able to achieve.

The results of the experiment indicate an important outcome for the RenalViT framework in comparison with CNN baselines as follows: classification accuracy = 98.96%, weighted precision = 99.02%, weighted recall = 98.96%, weighted F1-score = 98.99%, AUC-ROC=0.997. When compared to the best performing CNN baseline (EfficientNetB3: 75.16% accuracy), these results equate to significant increases of 23.80 percentage points (pp) accuracy, 22.80 pp precision and 23.31 pp F1 Score. The confusion matrix suggests that the classification of each disease category is near-perfect with all false negative rates < 2%, which includes the clinically most important Tumor class.

This PhD Thesis would be useful for researchers, academicians, healthcare professionals, and industry practitioners interested in CKD classification and detection based on medical imaging.



List of Publication(s):

- 1). Thacker, Smit, and Ravirajsinh Vaghela. "Assessing chronic kidney disease prediction models: a comparative analysis of smart AI and intelligent machine learning approaches." In 2024 international conference on advancements in smart, secure and intelligent computing (ASSIC), pp. 1-6. IEEE, 2024.
- 2). Smit Thacker; Ravirajsinh Vaghela. "KTransNet: A Hybrid Transformer-CNN Framework for Early-Stage Chronic Kidney Disease Detection Using Multi-Modal Renal Imaging". Volume. 11 Issue.5, May 2026 International Journal of Innovative Science and Research Technology (IJISRT) 37-49 <https://doi.org/10.38124/ijisrt/26May250>
- 3). Smit Thacker, Ravirajsinh Vaghela, and Dushyantsinh Rathod. "Kidney Disease Prediction Using Machine Learning" IAPQR Transactions, vol. 49, no. 2, 2024.