Improved Classification Learning from Highly Imbalanced Multi-Label Datasets of Inflamed Joints in [^{99m}Tc]Maraciclatide Imaging of Arthritic Patients by Natural Image and Diffusion Model Augmentation

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Introduction

- We classify the presence of inflammation in the finger and wrist joints of patients with Rheumatoid Arthritis from a dataset of 48 patients
- Our data consists of [^{99m}Tc]maraciclatide scans[1] with clinician defined segmentation labels of the normal tissue as well as low and high inflammation and the classification per joint (Fig 2)
- The dataset is both small and imbalanced, there are 98 images from 48 patients of both the Dorsal and Palmer views (Fig 1)

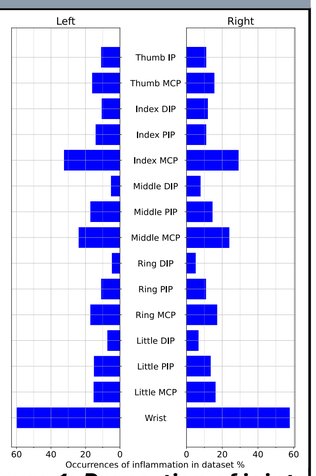
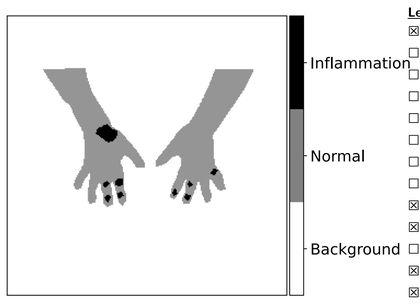


Figure 1: Proportion of joints inflamed within the dataset





Left	Right
☒**Wrist**	☐Wrist
☐Little MCP	☐Little MCP
☐Little Proximal IP	☒**Little Proximal IP**
☐Little Distal IP	☐Little Distal IP
☐Ring MCP	☐Ring MCP
☐Ring Proximal IP	☐Ring Proximal IP
☐Ring Distal IP	☐Ring Distal IP
☐Middle MCP	☐Middle MCP
☒**Middle Proximal IP**	☒**Middle Proximal IP**
☒**Middle Distal IP**	☒**Middle Distal IP**
☐Index MCP	☐Index MCP
☒**Index Proximal IP**	☐Index Proximal IP
☒**Index Distal IP**	☒**Index Distal IP**
☐Thumb MCP	☐Thumb MCP
☐Thumb IP	☐Thumb IP

Figure 2: An example [^{99m}Tc]maraciclatide scan with clinician defined segmentation maps and classification labels over the joints

Methods I

- We use a generative Image-to-Image model, Palette [2], to augment our dataset; the generative model is trained on the clinician defined labels learning a mapping between the segmentation labels and the [^{99m}Tc]maraciclatide images (Fig 3)
- We sample in the label space and generate the associated segmentation map using layperson defined labels per joint (Fig 4)

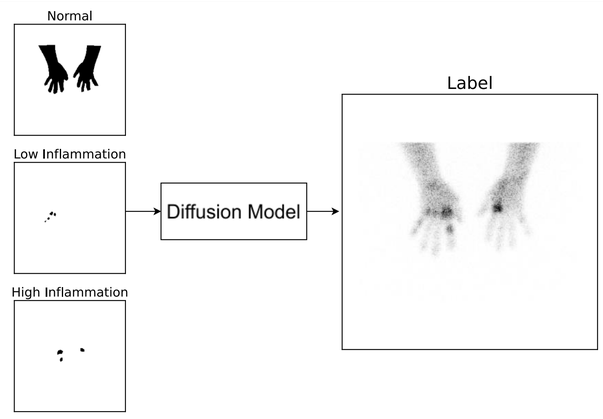


Figure 3: Palette Diffusion Image to Image model is trained on clinician defined labels to predict maraciclatide scan

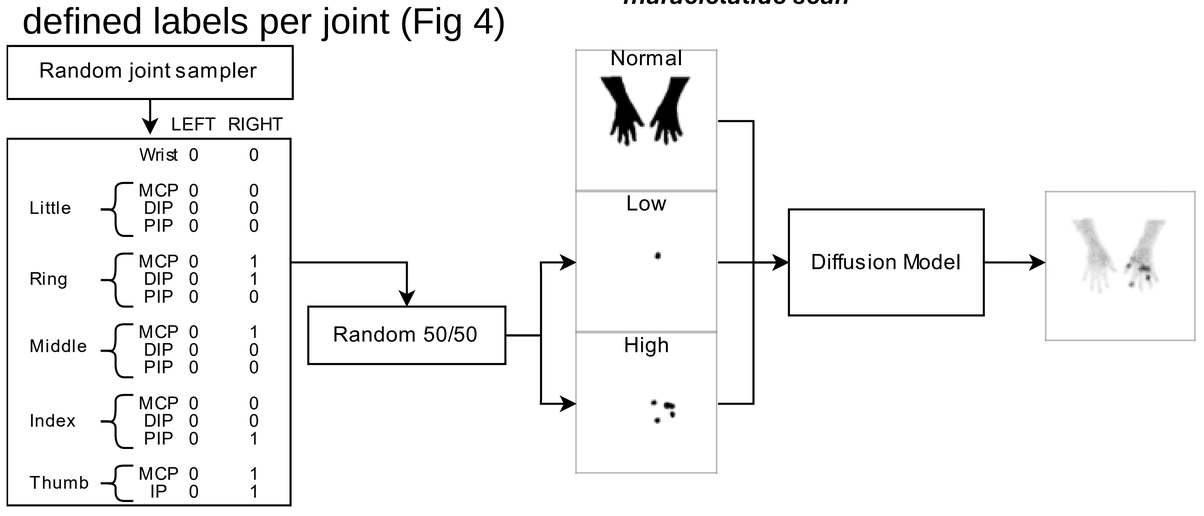


Figure 4: Samples are generated by randomly sampling in the label space, then using layperson labels to construct a synthetic segmentation map that corresponds to the label; This label is then passed into the diffusion model to generate a synthetic [99mTc]maraciclatide image

- In addition to [^{99m}Tc]maraciclatide augmentation we also augmented using hands from the 11K dataset (Fig 5, 6)

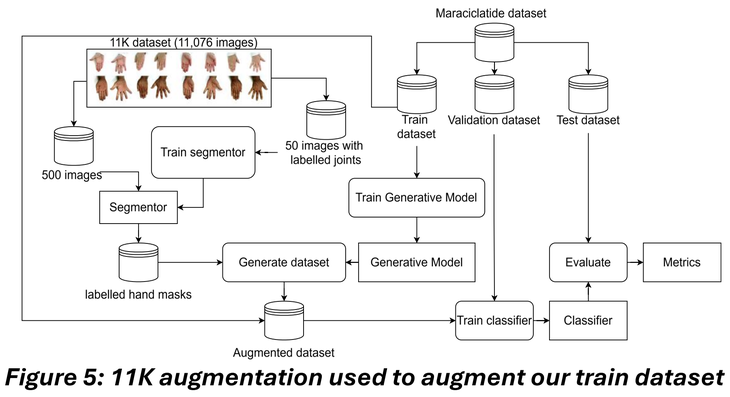


Figure 5: 11K augmentation used to augment our train dataset

Methods II

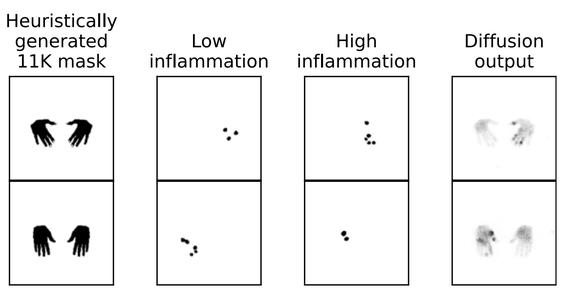


Figure 6: Example 11K synthetic images

- To create extra variation withing the individual joint labels, we use Perlin maps to vary the size and shape of the segmentation (Fig 7)

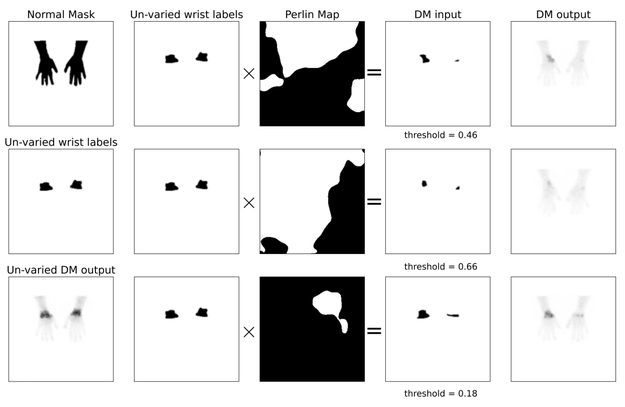


Figure 7: Perlin map augmentation of varying the inflammation size

- Each model was trained the same way but with different datasets
- We used a DenseNet with a growth rate of 32 trained in five-fold cross validation with 60% of our data for training, 20% for validation and 20% for test
- The validation dataset is used for early stopping, stopping model training when there was no improvement in the
- G-Mean Score GMS score over the validation dataset in 500,000 training samples
- All models used training augmentation of rotations, flipping, and cropping

Results

- The results show that increasing the size of the dataset leads to a general increase in the measured metrics on the test dataset
- Using 11K augmentation improved upon the baseline however the [^{99m}Tc]maraciclatide augmentation increased performance more
- From the un-augmented baseline of 0.79±0.05 accuracy, 0.45±0.07 F1 score, and 0.65±0.02 GMS; augmenting with 8,192 synthetic maraciclatide images achieved results of 91±0.02 accuracy 0.74±0.12 F1 score and 0.85±0.06 GMS (Fig 8)

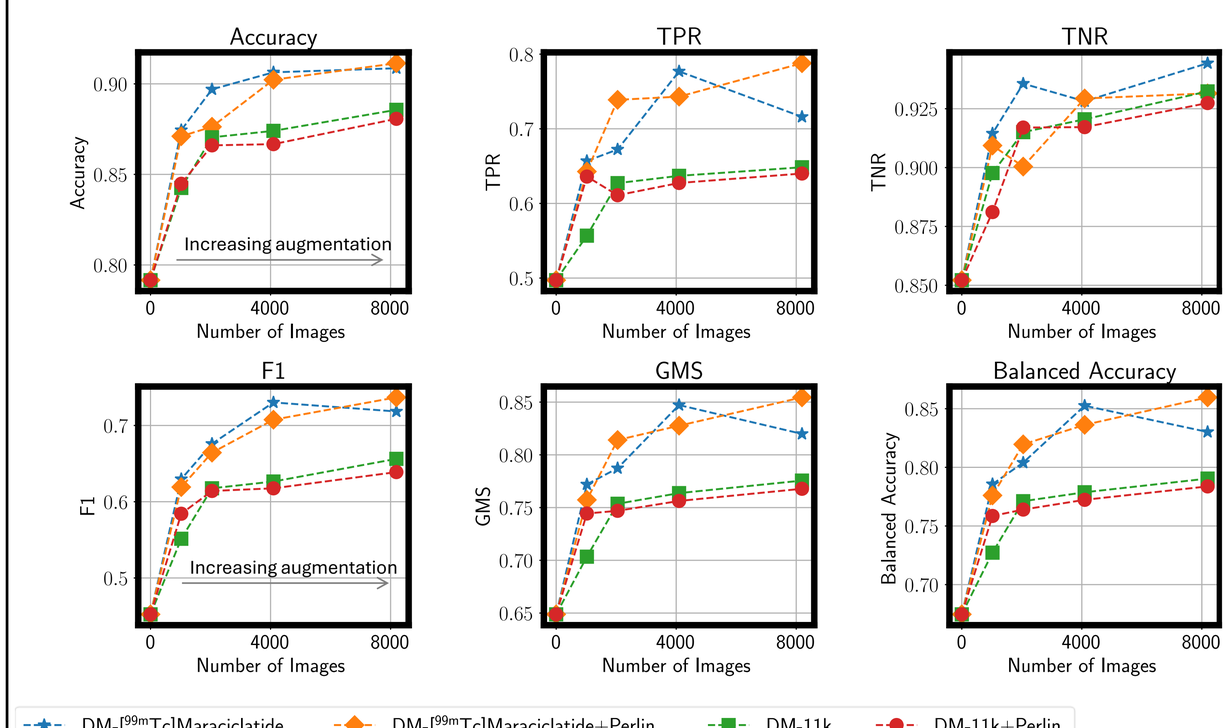


Figure 8: Graphs of performance on the test dataset averaged over a fivefold cross validation.

References

[1] Attipoe, et al: Imaging neoangiogenesis in rheumatoid arthritis (inira): whole-body synovial uptake of a 99mtc-labelled rgd peptide is highly correlated with power doppler ultrasound. Annals of the Rheumatic Diseases 79(9), 1254–1255 (2020)
[2] Saharia, et al. "Palette: Image-to-image diffusion models." *ACM SIGGRAPH 2022 conference proceedings*. 2022.
[3] Afifi, M.: 11k hands: Gender recognition and biometric identification using a large dataset of hand images. Multimedia Tools and Applications (2019)