CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

ORCA – Online Research @ Cardiff

This is an Open Access document downloaded from ORCA, Cardiff University's institutional repository:https://orca.cardiff.ac.uk/id/eprint/173115/

This is the author's version of a work that was submitted to / accepted for publication.

Citation for final published version:

Smith, R. L., Al-Battat, K., John, R., Li, M., Ackerley, I., Spezi, Emiliano , Wells, K., Morley, N. and Marshall, C. 2024. From radiomics to deep learning: Leveraging gramian matrix features in CNNs for NSCLC survival analysis. Presented at: 2024 IEEE Nuclear Science Symposium, Medical Imaging Conference and Room Temperature Semiconductor Detector Conference, Tampa, FL, USA, 26 October - 2 November 2024. 2024 IEEE Nuclear Science Symposium (NSS), Medical Imaging Conference (MIC) and Room Temperature Semiconductor Detector Conference (RTSD). IEEE, pp. 1-2. 10.1109/nss/mic/rtsd57108.2024.10657697

Publishers page: https://doi.org/10.1109/nss/mic/rtsd57108.2024.106...

Please note:
Changes made as a result of publishing processes such as copy-editing, formatting and page numbers may not be reflected in this version. For the definitive version of this publication, please refer to the published source. You are advised to consult the publisher's version if you wish to cite this paper.

This version is being made available in accordance with publisher policies. See http://orca.cf.ac.uk/policies.html for usage policies. Copyright and moral rights for publications made available in ORCA are retained by the copyright holders.

From Radiomics to Deep Learning: Leveraging Gramian Matrix Features in CNNs for NSCLC Survival Analysis.

R. L. Smith[1, 2], K. Al-Battat[2], R. John[4], M. Li[3], I. Ackerley[4], E. Spezi[3], K. Wells[4], N. Morley[2], C. Marshall[2]

[1] *Cardiff and Vale University Health Board, Medical Physics and Clinical Engineering, Cardiff, United Kingdom*

[2] *Cardiff University, Wales Research and Diagnostic PET Imaging Centre, Cardiff, United Kingdom*

[3] *Cardiff University, School of Engineering, Cardiff, United Kingdom*

[4] *University of Surrey, Centre for Vision Speech and Signal Processing, Guildford, United Kingdom*

Abstract

Deep learning has demonstrated effectiveness in PET-CT lesion detection [1] and interpreting complex glycotic uptake distributions [2]. Our prior work [3] pioneered the use of Gramian matrices to characterize and synthesize PET tumour heterogeneity. This study employs our "Titanium" features derived from the activation functions within the pretrained VGG-19 convolutional neural network (CNN). From this diverse feature set, we present our survival prediction model and validate the superior efficacy of "Titanium" features in enhancing predictive modeling of 2-year survival for non-small-cell lung cancer (NSCLC) patients compared to traditional IBSI Radiomic Features.

The model was evaluated on 381 NSCLC patients, expertly segmented and split into 80% training, 10% validation, and 10% testing sets. "Titanium" features were computed from activation functions across five CNN layers on three orthogonal tumor slices, providing a comprehensive 2.5D representation. This yielded 150 complex textural descriptors. Contrastingly, 203 traditional IBSI radiomic features were derived. Preprocessing included standard scaling, polynomial expansion, and L1-regularized logistic regression for feature selection. Data transformations and feature selection were determined solely from training the set to prevent data leakage. Prediction involved optimizing a multilayer perceptron on the validation set using cross-validation followed by independent testing on the held out set.

Our results revealed that the "Titanium" model achieved a Receiver Operating Characteristic (ROC) Area Under the Curve (AUC) of 0.83, significantly outperforming the traditional radiomic approach, which only achieved an AUC of 0.54. This 53.7% improvement in predictive power highlights the effectiveness of "Titanium" features in capturing more nuanced and predictive information and presents a sophisticated analytical technique for clinical predictive modelling of oncological outcomes.

References

[1] I. Ackerley, R. Smith, J. Scuffham, M. Halling-Brown, E. Lewis, E. Spezi, V. P. M.D., and K. Wells, "Using deep learning to detect oesophageal lesions in PET-CT," in Medical Imaging 2019: Biomedical Applications in Molecular, Structural, and Functional Imaging, vol. 10953, International Society for Optics and Photonics. SPIE, 2019, pp. 138 – 146.

[2] R. R. John, I. Ackerley, R. L. Smith, J. Scuffham, A. Robinson, V. Prakash, and K. Wells, "Automatic labeling of glycolytic volumes in pet using deep texture analysis," in 2023 IEEE Nuclear Science Symposium, Medical Imaging Conference (NSS MIC). IEEE, November 2023, pp. 1–2.

[3] R. L. Smith, R. R. John, I. Ackerley, K. Al-Battat, E. Alsyed, E. Spezi, and C. Marshall, "A deep texture metric for pet image quantification and image synthesis," in 2023 IEEE Nuclear Science Symposium, Medical Imaging Conference (NSS MIC). IEEE, November 2023, p. 1.