EMERALD

December 2022
Issue #2

The latest news, views, and announcements - Issue #2

Welcome to the second edition of the EMERALD newsletter.

Dear readers,

We're excited to share key updates from July 2022 to December 2022. Stay informed of the latest developments and achievements.

Enjoy,

The EMERALD Team

INSIDE

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Development of DBMS
Secure, efficient, and collaborative research data management.

—

Publications at Conferences and Journals

AI-driven research on CAD and NSCLC, focusing on diagnosis and explainability.

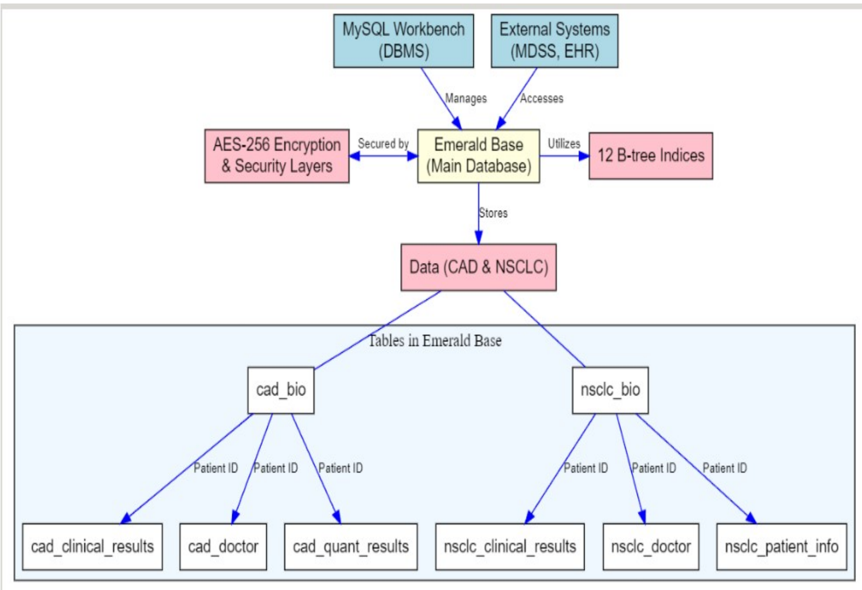
Progress catch-up

Even in its early stages, the EMERALD team has made significant strides in key research areas.

The project is taking shape through a combination of innovative methodologies, advanced AI applications, and impactful studies. Early efforts focused on building the necessary infrastructure, starting with the development of a Database Management System (DBMS) to support research and data analysis. These foundations have already led to multiple publications showcasing the potential of AI-driven diagnostics in medical imaging.

Development of Database Management System (DBMS)

Effective Organisation of the Test-Case Data



We are excited to introduce our state-of-the-art Database Management System (DBMS), specifically designed to support researchers in the study of Coronary Artery Disease (CAD) and Non-Small Cell Lung Cancer (NSCLC). This powerful system provides a centralized, secure, and structured platform for managing clinical data, demographic information, and medical imaging, ensuring seamless data integration and accessibility. With regular backups and strict access controls, the DBMS upholds data integrity and security, enabling researchers to collaborate effectively through tailored read-and-write permissions. Redundancy is minimized by preventing data duplication, while structured annotations enhance the context of patient data, offering deeper clinical insights. Built on a strong ethical framework, the system ensures patient anonymity, safeguarding sensitive information while maintaining research transparency. Designed for efficiency and ease of use, it features an intuitive interface that requires minimal training, along with advanced search and data dissemination capabilities to streamline analysis. By providing a comprehensive and ethical approach to CAD and NSCLC data management, the EMERALD DBMS empowers researchers to drive innovation and enhance medical advancements in cardiovascular and oncology research.

Presentation in IWBBIO2022, Gran Canaria, Spain

Date: 27 June 2022

In June 2022, Assoc. Prof. Nikolaos Papandrianos (Faculty member and Nuclear Medicine Specialist) attended the 9th International Work-Conference on Bioinformatics and Biomedical Engineering, IWBBIO 2022.

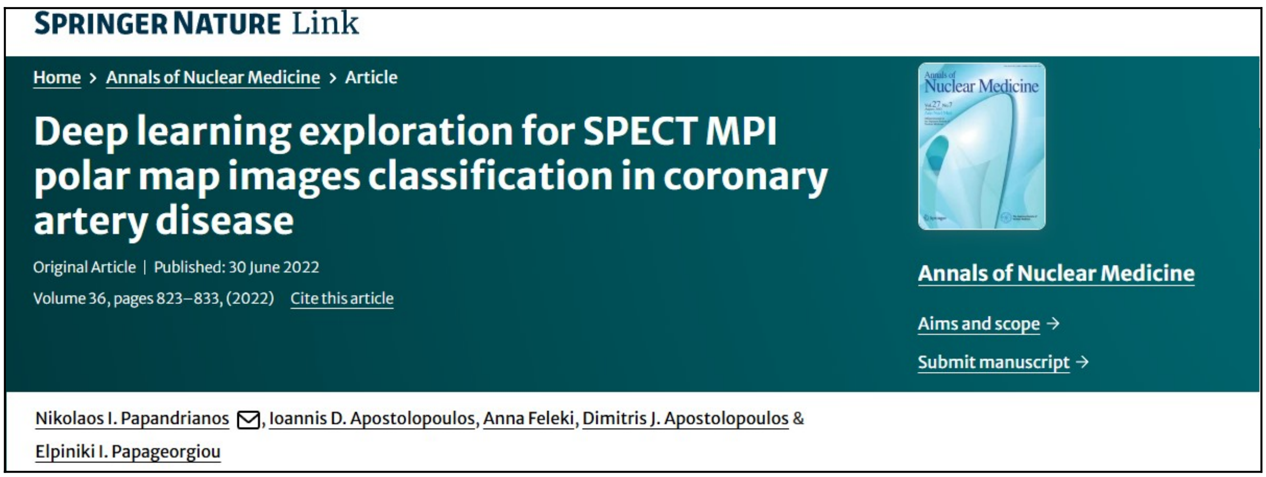
The conference unfolded on June 27-30, 2022, at the University of Granada in Gran Canaria, Spain. IWBBIO2022 gathered researchers exploring the realms of bioinformatics and biomedical engineering. Notably, Assoc. Prof. Nikolaos Papandrianos shared insightful research in his presentation, titled "**A Convolutional Neural Network Model for SPECT Myocardial Perfusion Images Classification**."

RGB-CNN model, a Convolutional Neural Network (CNN) model constructed from scratch was implemented and compared to the pre-trained VGG-16 network for CAD classification. The dataset included Single Photon Emission Tomography-Myocardial Perfusion Images (SPECT-MPI) images, where 100 correspond to infarction, 180 to ischemic, and 190 to normal cases. Data augmentation was also applied to improve generalization. The RGB-CNN achieved 94.21% accuracy, surpassing VGG-16's 84.37%. These results demonstrate its effectiveness in CAD diagnosis, highlighting its strong potential for classifying unseen data in nuclear medicine.

This contribution highlights advancements at the intersection of bioinformatics and deep learning, underscoring the pivotal role of Convolutional Neural Networks in classifying SPECT myocardial perfusion images.

Article in Annals of Nuclear Medicine

DOI: 10.1007/s12149-022-01762-4, Date: 30 June 2022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Deep learning exploration for SPECT MPI polar map images classification in coronary artery disease

Original Article | Published: 30 June 2022

Volume 36, pages 823–833, (2022) Cite this article

Annals of Nuclear Medicine

Aims and scope →

Submit manuscript →

Nikolaos I. Papandrianos, Ioannis D. Apostolopoulos, Anna Feleki, Dimitris J. Apostolopoulos & Elpiniki I. Papageorgiou

Our team published a study named "Deep learning exploration for SPECT MPI polar map images classification in coronary artery disease" in the Journal of Annals of Nuclear Medicine (2022), Volume 36, pages 823–833

The authors conducted experiments using the RGB-CNN model, a CNN trained from scratch, for CAD diagnosis with Polar Maps data. The study included 314 patients, comprising 144 normal and 170 pathological cases. The dataset consisted of stress and rest Polar Maps images in both attenuation-corrected (AC) and non-corrected (NAC) formats. To benchmark performance, transfer learning was also applied using the VGG-16 model as a pre-trained network. Preprocessing steps involved data normalization, shuffling, and augmentation techniques such as rotation, zooming, flipping, and rescaling to enhance data variability. Following extensive experimentation, the final RGB-CNN architecture was composed of four convolutional layers with 2, 4, 8, and 16 nodes, followed by two fully connected layers with 16 nodes each. The input image size was set to 200×200 pixels. For the VGG-16 model, 13 layers of the original architecture were retained, with two additional fully connected layers for adaptation to the dataset. Performance evaluation using 5-fold cross-validation demonstrated that the RGB-CNN model achieved an accuracy of 92.07% with a loss of 0.219, while the VGG-16 model achieved a higher accuracy of 95.83%. Despite its simpler structure, the RGB-CNN model exhibited performance comparable to the more complex VGG-16, indicating that lightweight CNN architectures can achieve high diagnostic accuracy while reducing computational cost and system complexity. Check the full article here.

Article in Journal of Clinical Medicine

DOI: 10.3390/jcm11133918, Date: 5 July 2022

Journal of Clinical Medicine

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Open Access Article

Deep Learning-Based Automated Diagnosis for Coronary Artery Disease Using SPECT-MPI Images

by Nikolaos I. Papandrianos [1,*], Anna Feleki [1], Elpiniki I. Papageorgiou [1] and Chiara Martini [2,3]

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J. Clin. Med. **2022**, *11*(13), 3918; https://doi.org/10.3390/jcm11133918

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(This article belongs to the Section Cardiovascular Medicine)

Our team published a study named "Deep Learning-Based Automated Diagnosis for Coronary Artery Disease Using SPECT-MPI Images" in the Journal of J. Clin. Med. 2022, 11(13), 3918

The authors investigated CNNs, for the classification of SPECT-MPI images in the diagnosis of CAD. Three CNN architectures were evaluated: an RGB-CNN designed from scratch, along with VGG-16 and DenseNet-121, both of which employed transfer learning. The dataset comprised 647 images, categorized into infarction, ischemic, and normal cases, with data augmentation applied to address dataset size limitations. The techniques that are applied in the current research are: rescale, rotation, range, width shift range, height shift range, shear range, zoom range, horizontal flip, and vertical flip. The aim of this procedure was to achieve generalizability and prevent overfitting. The dataset was split into three parts: training, validation, and testing. Training had 85% of the total dataset and testing had the remaining 15%. From the training dataset, 80% was provided for training, whereas 20% of training was supplied for validation. The RGB-CNN architecture processed images at 300 × 300 pixels, with a batch size of 32. It featured four convolutional layers with 16, 32, 64, and 128 nodes, accordingly, followed by two dense layers of 128 neurons each. Regarding VGG-16, the best architecture included 200 × 200-pixel size, 32 batch size, 0.2 drop rate, 400 epochs, 14 true trainable parameters, global average pooling, and two fully connected layers with 32 nodes each. DenseNet-121's best architecture consisted of 250 × 250 for pixel size, 32 for batch size, 0.2 drop rate, 400 epochs, 12 true trainable layers, global average pooling, and 2 fully connected layers with 32 nodes each. Among the tested models, the RGB-CNN achieved the highest accuracy of 91.86%, surpassing VGG-16 (88.54%) and DenseNet-121 (86.11%). Check the full article here.

Article in Applied Sciences

DOI: 10.3390/app12157592, Date: 24 July 2022

applied sciences

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An Explainable Classification Method of SPECT Myocardial Perfusion Images in Nuclear Cardiology Using Deep Learning and Grad-CAM

by Nikolaos I. Papandrianos [1], Anna Feleki [1], Serafeim Moustakidis [1,2], Elpiniki I. Papageorgiou [1,*], Ioannis D. Apostolopoulos [3] and Dimitris J. Apostolopoulos [4]

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Appl. Sci. **2022**, *12*(15), 7592; https://doi.org/10.3390/app12157592

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(This article belongs to the Special Issue Information Processing in Medical Imaging)

Our team published a study named "An Explainable Classification Method of SPECT Myocardial Perfusion Images in Nuclear Cardiology Using Deep Learning and Grad-CAM" in the Journal of Appl. Sci. 2022, 12(15), 7592

The authors developed an explainable deep learning pipeline by designing and training a CNN model from scratch, named RGB-CNN, for the classification of SPECT-MPI images. The study included 625 patients, capturing both stress and rest imaging states, with cases categorized into 127 infarction, 241 ischemic, and 257 normal instances. Preprocessing steps involved data normalization, shuffling, and dataset splitting, with 15% allocated for testing, 20% for validation, and 80% for training. To mitigate overfitting, data augmentation techniques such as flipping and scaling were applied. The CNN architecture consisted of four convolutional layers (16-32-64-128 nodes) followed by two fully connected layers, achieving an accuracy of 93.3% and an AUC of 94.58%. To enhance model transparency and interpretability, Grad-CAM was utilized to generate heatmaps, identifying the most influential regions contributing to predictions. These heatmaps were overlaid on the original images, allowing nuclear medicine experts to better understand the model's decision-making process. The results demonstrated strong alignment between the model's highlighted regions and nuclear diagnoses, particularly for infarction and ischemia, reinforcing the reliability of the approach. Additionally, the model was evaluated on previously unseen data to simulate real-world diagnostic scenarios, confirming its generalizability and clinical applicability. Check the full article here.

Article in Machine Learning & Knowledge Extraction

DOI: 10.3390/make4040040, Date: 21 September 2022

machine learning & knowledge extraction

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Open Access Review

Artificial Intelligence Methods for Identifying and Localizing Abnormal Parathyroid Glands: A Review Study

by Ioannis D. Apostolopoulos [1,*], Nikolaos I. Papandrianos [2], Elpiniki I. Papageorgiou [2] and Dimitris J. Apostolopoulos [3]

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Mach. Learn. Knowl. Extr. **2022**, *4*(4), 814-826; https://doi.org/10.3390/make4040040

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(This article belongs to the Collection Extravaganza Feature Papers on Hot Topics in Machine Learning and Knowledge Extraction)

Our team published a study named "Artificial Intelligence Methods for Identifying and Localizing Abnormal Parathyroid Glands: A Review Study" in the Journal of Mach. Learn. Knowl. Extr. 2022, 4(4), 814-826;

The authors conducted a comprehensive review of AI applications, particularly machine learning (ML) and deep learning (DL) methods, for the identification and localization of Parathyroid Glands (PGs) and the detection of conditions such as Primary Hyperparathyroidism (PHPT), Parathyroid Adenoma (PTA), and Multiglandular Disease (MGD). The study examined 13 relevant publications, focusing on both preoperative and intraoperative AI implementations. Among the reviewed studies, 42% concentrated on PG detection, while 33% focused on PG localization. AI-driven approaches have shown promising results in preoperative classification tasks, with sensitivity ranging from 82% to 96% and accuracy between 91% and 96%. However, PG localization remains a challenging and underexplored area, primarily due to its complexity and the high risk of false positives. The review also highlighted several limitations in existing studies, including small sample sizes, inadequate parameter tuning, and inconsistent validation methods, making it difficult to compare results across studies. Notably, none of the reviewed research integrated both clinical and imaging data, which could significantly enhance diagnostic accuracy and reduce false positives. A key recommendation was the development of large-scale, publicly available image datasets to drive advancements in DL techniques and improve AI-assisted surgical tools. The study also emphasized the importance of explainable AI (XAI), advocating for post-hoc interpretability methods such as Grad-CAM, which could enhance trust and usability in clinical practice. While the findings in the literature were encouraging, the authors stress that future research should focus on developing robust, well-documented AI models with validated methodologies, ensuring reproducibility and real-world applicability in PG identification and disease detection. Check the full article here.


diagnostics

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Deep Learning Assessment for Mining Important Medical Image Features of Various Modalities

by Ioannis D. Apostolopoulos [1,*], Nikolaos D. Papathanasiou [2], Nikolaos I. Papandrianos [3], Elpiniki I. Papageorgiou [3] and George S. Panayiotakis [1]

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(This article belongs to the Special Issue Intelligent Imaging in Nuclear Medicine)

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Article in Diagnostics

DOI: 10.3390/diagnostics12102333, Date: 27 September 2022

Our team published a study named "Deep Learning Assessment for Mining Important Medical Image Features of Various Modalities" in the Journal of Diagnostics 2022, 12(10), 2333

The authors evaluated DL models for their effectiveness in extracting and identifying potential image biomarkers across eleven diverse biomedical imaging datasets, encompassing SPECT, CT, X-ray, histopathology, and microscopy images. The study found that training CNNs from scratch—rather than relying solely on transfer learning—led to superior performance when high-quality, large-scale datasets were available, enabling the models to learn clinically relevant features more effectively. The research also explored the robustness of CNNs to variations in imaging acquisition devices, demonstrating that deep models can generalize well across different imaging conditions. To enhance interpretability, Grad-CAM visualizations were employed, confirming that the models successfully highlighted clinically significant diagnostic regions, thereby improving explainability and fostering clinical trust. Among the tested architectures, Feature Fusion-VGG19 emerged as the top-performing model, surpassing state-of-the-art CNNs in both classification accuracy when trained from scratch and stability when used for transfer learning. Due to its strong generalization ability across multiple imaging modalities, FF-VGG19 was proposed as a robust baseline model for medical image classification, covering PET, CT, X-rays, dermoscopy, and histopathology. These findings underscore the critical role of deep learning in biomedical imaging, particularly in identifying key diagnostic features, and highlight the importance of integrating XAI techniques to improve transparency and reliability in clinical decision-making. Check the full article here.

IISA 2022 Presentation, Corfu, Greece

DOI: 10.1109/IISA56318.2022.9904340, Date: 30 September 2022

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A Convolutional Neural Network-based explainable classification method of SPECT myocardial perfusion images in nuclear cardiology

Publisher: IEEE　Cite This　PDF

Nikolaos I. Papandrianos ; Anna Feleki ; Serafeim Moustakidis ; Elpiniki I. Papageorgiou　**All Authors**

Prof. Elpiniki Papageorgiou (PI of the EMERALD project) and Nikolaos Papandrianos attended the 13th International Conference on Information, Intelligence, Systems & Applications (IISA), 18-20 July, Corfu, Greece, 2022.

IISA 2022 aimed to unite researchers exploring AI and computational intelligence applications across diverse scientific domains. Prof. Elpiniki Papageorgiou, representing EMERALD at the University of Thessaly, contributed by presenting an innovative approach titled **'A Convolutional Neural Network-based Explainable Classification Method of SPECT Myocardial Perfusion Images in Nuclear Cardiology**.'

An explainable CNN pipeline was developed for CAD assessment. The proposed RGB-CNN model incorporated pre- and post-processing techniques, including data normalization, shuffling, and augmentation (rescaling, flipping, rotation) to enhance performance. Trained on 630 patient cases, the model achieved 94.06% accuracy and an AUC of 95.41%, effectively detecting ischemia and infarction in SPECT-MPI images. To improve interpretability, Gradient-weighted Class Activation Mapping (Grad-CAM) highlighted key features in yellow using the Viridis colormap, offering clinicians insights into the model's decision-making. Check the full article here.

This research delves into the intersection of Convolutional Neural Networks and explainability, particularly in the context of classifying SPECT myocardial perfusion images, reinforcing trust in AI-assisted clinical decision-making. Prof. Papageorgiou's presentation showcased advancements at the forefront of AI applications, emphasizing the importance of interpretability in cutting-edge classification methods for nuclear cardiology.

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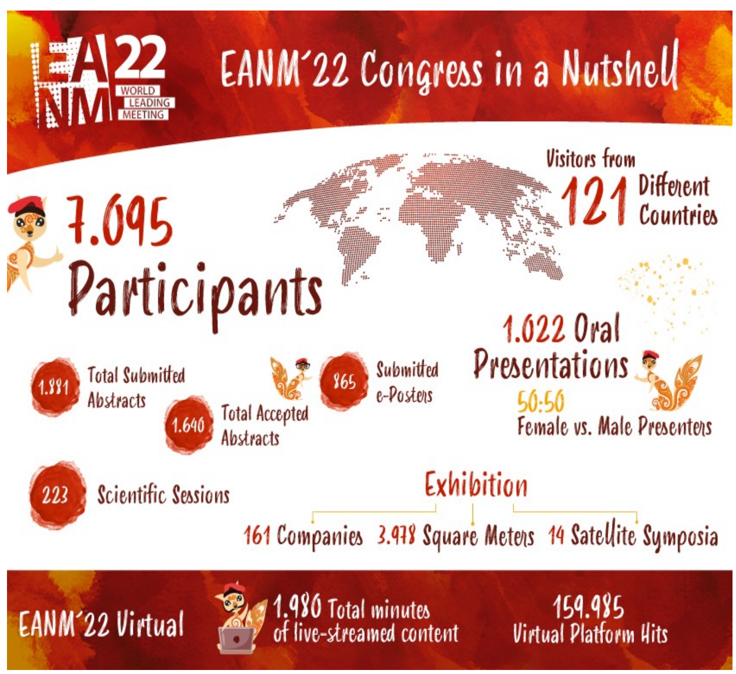
Date: 15-19 October 2022

At the European Association of Nuclear Medicine (EANM) 2022, the Emerald team delivered two pivotal virtual presentations, emphasizing the role of deep learning in diagnosing coronary artery disease using SPECT MPI images.

In the first presentation, "**Deep learning for automatic diagnosis of coronary artery disease using SPECT MPI images**.", Papandrianos et al. presented an innovative approach leveraging CNNs for automatic diagnosis of CAD using SPECT-MPI slices. The developed RGB-CNN model demonstrated remarkable accuracy, achieving 91.86%, surpassing the performance of VGG-16 and DenseNet-121 models at 88.54% and 86.11% respectively. By employing supervised learning techniques and robust evaluation metrics, their method showcased the potential of deep learning in nuclear medicine. This research not only highlighted the efficacy of CNNs in CAD diagnosis but also underscored the importance of AI-driven solutions in enhancing clinical decision-making processes, ultimately improving patient care in cardiovascular medicine.

The second presentation, **"Explainable prediction of coronary artery disease in nuclear medical imaging using deep learning**," addressed the opacity of deep learning models in CAD diagnosis. Papandrianos et al. introduced an innovative, explainable deep learning pipeline. The RGB-CNN model, augmented with pre- and post-processing techniques, achieved exceptional accuracy of 93.3% and AUC of 94.58% in classifying CAD status from SPECT MPI images. Leveraging Grad-CAM visualization, their approach not only delivers accurate predictions but also provides transparent insights into model decisions. By bridging the gap between deep learning complexity and interpretability, this research empowers nuclear physicians with rapid, confident judgments, enhancing diagnostic accuracy in nuclear medicine. These findings underscore the potential of explainable AI in revolutionizing CAD diagnosis, ensuring robust and efficient clinical decision-making processes.



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