January 2024
Issue #5

EMERALD

The latest news, views, and announcements - Issue #5

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Implementation of CAD clinical, imaging, and multimodal form

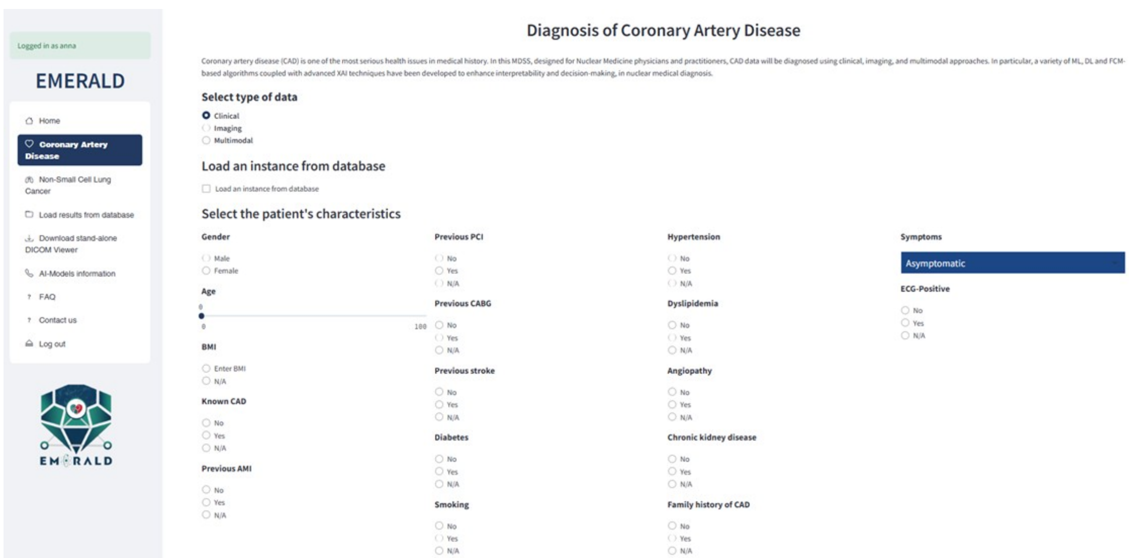
Welcome to the fifth edition of the EMERALD newsletter.

Dear readers,

We are pleased to announce the release of the fifth edition of the EMERALD newsletter. This issue covers significant developments from November 2023 to January 2024. We aim to keep you informed about noteworthy events and updates during this period.

Enjoy,

The EMERALD Team



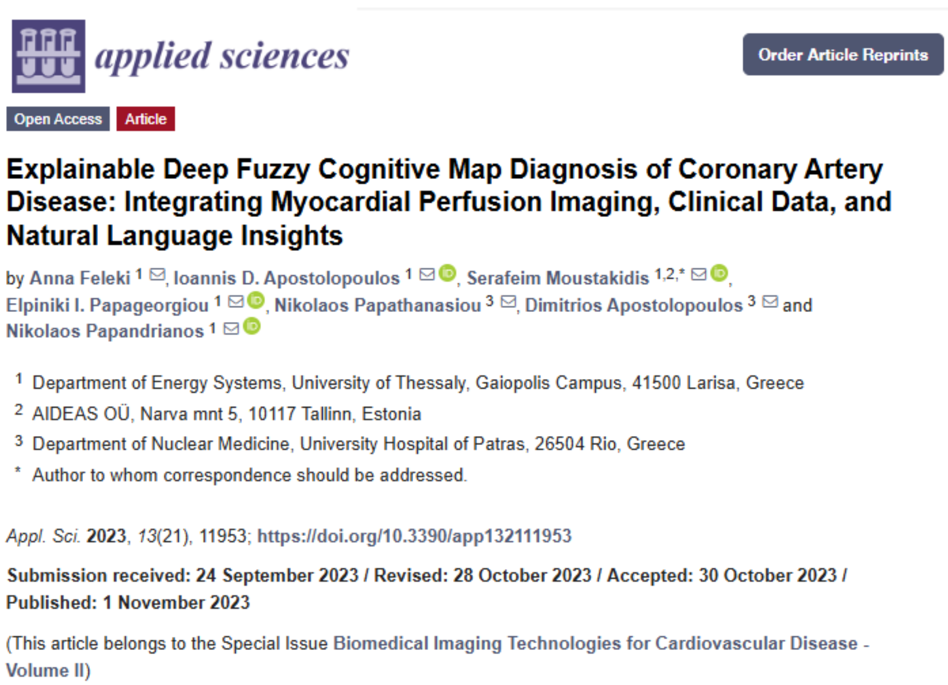
Progress catch-up

We are advancing the integration of AI technologies into clinical practice through the development of transparent, data-driven tools. This stage of the project marks significant progress in model explainability, research dissemination, and the initial implementation of our Medical Decision Support System (MDSS).

The recent phase of the EMERALD project reflects steady progress in both scientific exploration and practical implementation. Our work continues to bridge the gap between AI research and clinical decision support, with recent presentations and publications focusing on explainable methodologies for disease diagnosis. A highlight of this period is the implementation of the MDSS, showcasing its potential through interactive forms for clinical, imaging, and multimodal data. These developments demonstrate EMERALD's commitment to building transparent, AI-powered tools for future healthcare applications.

New Article in Applied Sciences

DOI: https://doi.org/10.3390/app132111953, Date: 1 November 2023



applied sciences

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Open Access Article

Explainable Deep Fuzzy Cognitive Map Diagnosis of Coronary Artery Disease: Integrating Myocardial Perfusion Imaging, Clinical Data, and Natural Language Insights

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

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Appl. Sci. **2023**, *13*(21), 11953; https://doi.org/10.3390/app132111953

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(This article belongs to the Special Issue Biomedical Imaging Technologies for Cardiovascular Disease - Volume II)

Our team published an article in the Journal, of Applied Sciences, under the title "Explainable Deep Fuzzy Cognitive Map Diagnosis of Coronary Artery Disease: Integrating Myocardial Perfusion Imaging, Clinical Data, and Natural Language Insights".

This work presents DeepFCM, a hybrid model developed for the classification of CAD pathology by combining patient demographic information with Polar Map imaging data. A feature selection process was applied to retain the most relevant clinical variables, enhancing the model's efficiency. DeepFCM integrated the selected clinical features with predictions generated by RGB-CNN, a convolutional neural network (CNN) trained from scratch, treating them as input concepts within a Fuzzy Cognitive Map (FCM). This fusion of structured clinical data and imaging-based predictions enabled a more comprehensive and interpretable representation of the diagnostic process. The interconnections among concepts were initially defined by domain experts using fuzzy sets, while Particle Swarm Optimization (PSO) was employed to refine the strength of these relationships, enabling a more accurate and interpretable diagnostic process. By employing the subset of clinical features and the Convolutional Neural Network (CNN) prediction attained from Polar Maps images, the proposed model attained an accuracy rate of 83.07% with a standard deviation of 4.72%. DeepFCM's explainability regarding CAD diagnosis, integrating Gradient-weighted Class Activation Mapping (Grad-CAM) and Natural Language Processing (NLP). Grad-CAM highlighted the crucial regions in Polar Maps images that showcased pathology, thereby aiding in the interpretation of CNN's predictions by pinpointing the specific areas of the images that influenced the diagnostic outcomes. This integration of Grad-CAM enhanced the transparency and interpretability of the diagnostic process, allowing medical professionals to understand better and trust the model's decisions. The utilization of NLP included the creation of a prompt with the analysis of the clinical values of an instance, the DeepFCM generated interconnections among concepts, the CNN and DeepFCM prediction, and the actual label. This prompt was inserted into the Application Programming Interface (API) constructed from OpenAI, Generative Pre-Trained Transformer (GPT) to justify the DeepFCM results into human-understandable language and demonstrate the key contributors to its final diagnosis. Check the full article HERE.

IISA 2023

DOI: 10.1109/IISA59645.2023.10345912 , Date: 15 December 2023

The EMERALD research team participated at the 14th International Conference on Information, Intelligence, Systems & Applications (IISA) 2023, presenting significant advancements in AI-driven diagnostic methodologies for non-small cell lung cancer (NSCLC).


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Deep Fuzzy Cognitive Map methodology for Non-Small Cell Lung Cancer diagnosis based on Positron Emission Tomography imaging

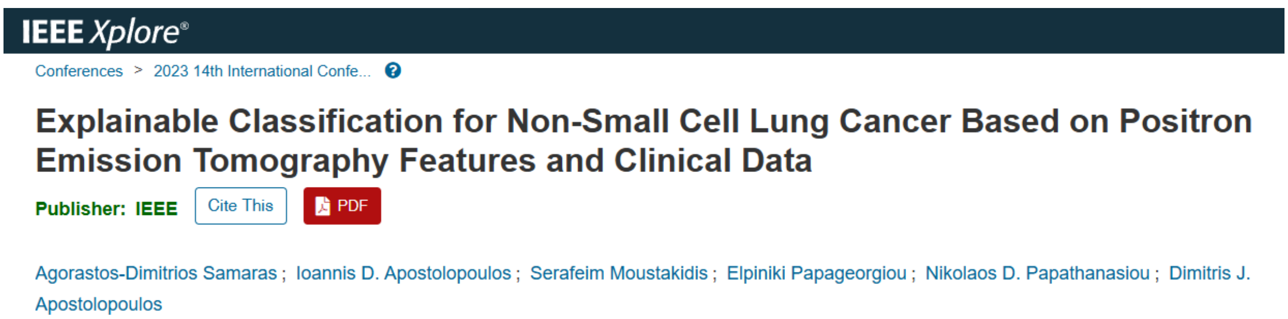
Publisher: IEEE   Cite This   PDF

Anna Feleki ; Ioannis D. Apostolopoulos ; Elpiniki Papageorgiou ; Serafeim Moustakidis ; Nikolaos D. Papathanasiou ; Dimitris J. Apostolopoulos   All Authors

First presentation: "**Deep Fuzzy Cognitive Map Methodology for Non-Small Cell Lung Cancer Diagnosis Based on Positron Emission Tomography Imaging**". Feleki et al. developed DeepFCM for the early characterization of solitary pulmonary nodules (SPNs) using PET/CT imaging. The model incorporated as input concepts the SUVmax, SPN diameter, and predictions generated by RGB-CNN, a CNN trained from scratch. By combining imaging data with clinical data, DeepFCM enhanced both diagnostic accuracy and interpretability in SPN classification. Fuzzy sets were used to initialize the interconnections among concepts, capturing expert knowledge within the FCM framework. To refine these relationships, PSO was employed, enabling the adaptive learning of concept interconnections for improved model performance and interpretability. The proposed DeepFCM model demonstrated impressive performance, achieving an accuracy of 94.71%, sensitivity of 92.06%, and specificity of 96.98%. This method not only provides high accuracy in diagnosing NSCLC but also ensures transparency by explaining the importance of each feature, thereby enhancing the interpretability and reliability of the diagnostic process. This advancement underscores the potential of integrating fuzzy cognitive maps with deep learning for precise and explainable cancer diagnosis. Check the full article here.

IISA 2023

DOI: 10.1109/IISA59645.2023.10345893, Date: 15 December 2023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Explainable Classification for Non-Small Cell Lung Cancer Based on Positron Emission Tomography Features and Clinical Data

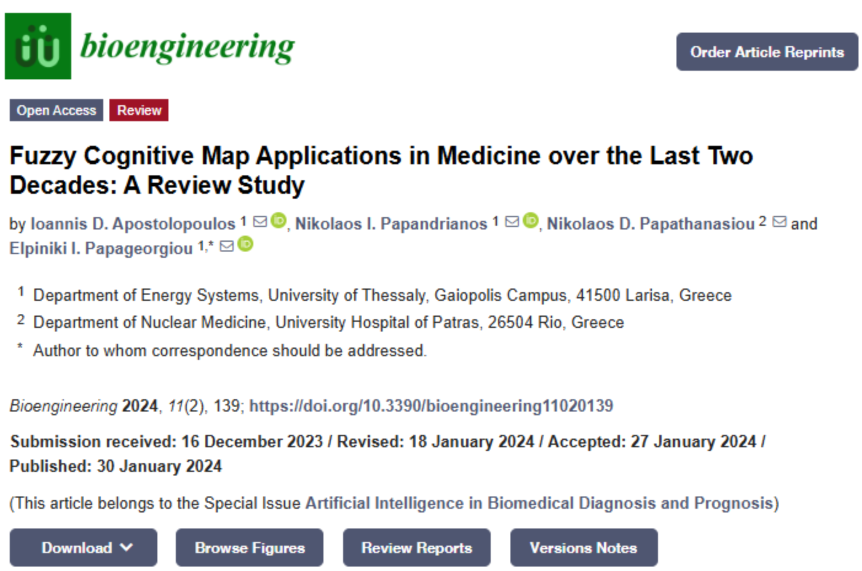
Publisher: IEEE | Cite This | PDF

Agorastos-Dimitrios Samaras ; Ioannis D. Apostolopoulos ; Serafeim Moustakidis ; Elpiniki Papageorgiou ; Nikolaos D. Papathanasiou ; Dimitris J. Apostolopoulos

Second presentation: " Explainable Classification for Non-Small Cell Lung Cancer Based on Positron Emission Tomography Features and Clinical Data. Samaras et al. presented a comprehensive computer-aided classification model for NSCLC, focusing on differentiating benign and malignant SPNs using clinical data. The study utilized biometric and clinical data from 243 patients, employing four machine learning (ML) algorithms to develop prediction models. The AdaBoost algorithm emerged as the most accurate, achieving 94.33% accuracy and a 95.71% true positive rate. SHAP analysis (SHapley Additive exPlanations) was also incorporated to identify the most influential clinical characteristics contributing to the model's predictions. The SUV uptake index was identified as the most impactful feature, followed by the glucose (GLU) index and the patient's gender. This added layer of explainability further enhanced the transparency and clinical relevance of the ML model. This research demonstrates the efficacy of ML in improving NSCLC diagnosis, providing clear insights into model functionality and boosting confidence in AI-driven diagnostic tools. Check the full article here.

New Article in BioEngineering

DOI: https://doi.org/10.3390/bioengineering11020139, Date: 30 January 2024


bioengineering

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Open Access Review

Fuzzy Cognitive Map Applications in Medicine over the Last Two Decades: A Review Study

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

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Bioengineering **2024**, *11*(2), 139; https://doi.org/10.3390/bioengineering11020139

Submission received: 16 December 2023 / Revised: 18 January 2024 / Accepted: 27 January 2024 / Published: 30 January 2024

(This article belongs to the Special Issue Artificial Intelligence in Biomedical Diagnosis and Prognosis)

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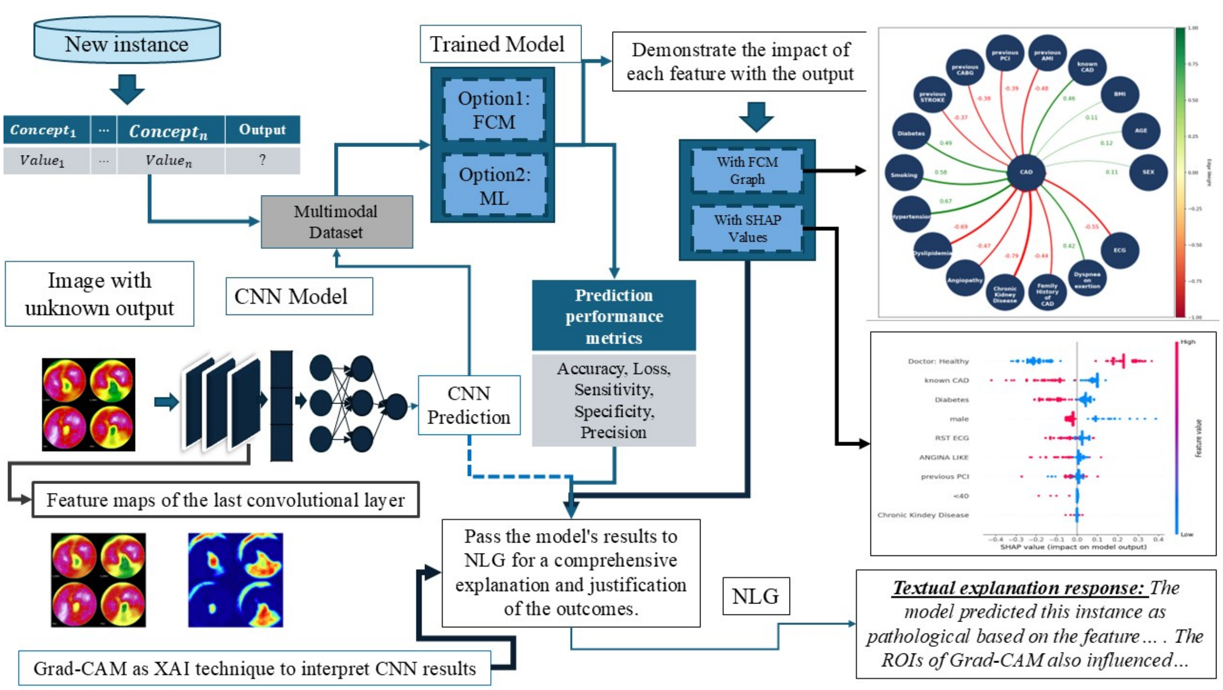
Our team published an article titled "Fuzzy Cognitive Map Applications in Medicine over the Last Two Decades: A Review Study" in the Journal BioEngineering.

This review highlighted the pivotal role of FCMs in healthcare, emphasizing their capacity to model intricate relationships among medical variables. By systematically examining literature from the past two decades, the study showcased FCM applications in areas like diagnosis, prognosis, treatment planning, and risk assessment. Despite their proven strengths in these areas, the review also identified key limitations and discusses avenues for advancing FCM methodologies, including enhancing their dynamic adaptability and extending their capabilities to integrate multimodal data sources for broader medical applications. Check the full article here.

Development of Medical Decision Support System

(Link: Access the EMERALD website and navigate to the 'MDSS' tab)

Our team developed the Medical Decision Support System (MDSS) and is now live in its initial stage, featuring the homepage and interactive forms for Coronary Artery Disease (CAD). The current version includes structured input for clinical data, imaging data, and their multimodal integration, allowing users to explore the system's core functionality.



The MDSS is developed to support multimodal diagnosis for Coronary Artery Disease (CAD), enabling clinicians to perform predictions based on clinical data, imaging data (e.g., Polar Maps), or a combination of both. This flexibility allows the system to generate accurate outcomes even when only one data modality is available. When both clinical and imaging inputs are integrated, the MDSS enhances its diagnostic capabilities, offering a more complete and explainable decision-support process.

The CAD Multimodal Form in the MDSS is designed to collect key patient information for AI-driven diagnosis. The key steps for a multimodal diagnosis are the following:

- **Insert Clinical Data**: Collection of key patient information, including demographics and cardiovascular history (gender, age, BMI, previous CAD, AMI, PCI, CABG, stroke, family history, diabetes, hypertension, etc.).
- **Insert Imaging**: Upload of a Polar map image.
- **Select CNN Model**: For imaging-based prediction, nuclear experts can select between the RGB-CNN—trained from scratch—or established pre-trained models like VGG-16 and VGG-19 to generate diagnostic outputs from the image.

- **Construction of the multimodal dataset**: The instance is automatically constructed by concatenating the clinical data with the CNN predictions derived from the CNN.
- **Select Model (FCM or ML)**: For the multimodal prediction, the nuclear expert has to choose between DeepFCM or Machine Learning (ML) models.
- **Perform Prediction**: Run the selected model to generate the multimodal prediction.
- **XAI techniques to analyze the impact of each factor**: In DeepFCM, graphical visualizations illustrate how each factor influences the final diagnosis, while in the case of ML models, SHAP plots are used to highlight and rank the most impactful clinical features.
- **Grad-CAM as XAI technique to interpret CNN prediction**: Grad-CAM based on the generated feature maps from the last convolutional layer demonstrates the most pathological regions of the image, showcasing the decision-making process of CNN.
- **Textual Explanation**: The NLG response delivers a concise and interpretable textual explanation, justifying the prediction made by DeepFCM through its learned interconnections or by the ML model via SHAP-derived feature importance. This explanation highlights the most influential characteristics, helping clinicians understand the rationale behind the AI's decision.

ΕΛ.Ι.Δ.Ε.Κ.
Ελληνικό Ίδρυμα Έρευνας & Καινοτομίας

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