Doctoral Dissertation
Doctoral Program in Bioengineering and Medical Surgical Sciences (38th Cycle)

AI-Driven, Interpretable Pattern Recognition for Multimodal Medical Data in Clinical Applications

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Summary

Modern healthcare faces growing challenges in delivering accurate, timely, and scalable diagnostic support. The era of precision medicine underscores that a broad spectrum of pathological conditions including viral and bacterial infections, skin and lung cancers, and neurological and psychiatric disorders require diagnostic solutions that extend beyond traditional assessments. This thesis explores the use of artificial intelligence (AI) and explainable machine learning to address these needs, developing pattern recognition tools in vocal analysis, radiological imaging, and RGB-based facial and dermatological studies.

The research presents AI-driven methods that extract discriminative emotional and behavioral patterns from infant and adult vocalizations and facial expressions, while also uncovering subtle clinical signals in pediatrics chest X-rays and Skin RGB images. By combining deep learning with machine-learning pipelines for feature optimization and explainable AI, the resulting models are robust and interpretable, supporting early pattern diagnosis and clinician-facing decision making.

A key focus is interpretability, ensuring clinicians can trust AI predictions. Techniques such as Gradient-Weighted Class Activation Mapping (Grad-CAM), Local Interpretable Model-Agnostic Explanations (LIME), and Occlusion sensitivity make model outputs transparent and clinically meaningful. This commitment to explainability also meets industrial and regulatory expectations, where accountability and trust are essential.

Grounded in industrial collaboration, the thesis emphasizes scalability, deployment readiness, and compliance with frameworks such as the European Union Artificial Intelligence Act (EU AI Act) and FDA guidelines. Collectively, the work offers a pathway toward industry-ready AI solutions that can enhance diagnostics, foster trust, and accelerate adoption in real-world healthcare.