Using Deep Learning and 5G to improve cardiovascular emergency management

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***Abstract*—This proposal explores the integration of a complex neural network to enhance the efficiency and efficacy of medical interventions during cardiovascular emergencies. By leveraging emerging technologies such as 5G and ML, the initiative seeks to revolutionize traditional emergency response mechanisms. The proposed system utilizes Smart Ambulances equipped with digital diagnostic tools and cloud-connected databases, ensuring rapid and reliable medical diagnosis and treatment in real-time. This approach not only facilitates immediate patient care but also supports medical decisions with ML-driven data analysis, offering a potential shift towards more autonomous emergency medical services. Key challenges addressed include ensuring data privacy, optimizing network performance, and building trust in ML applications through transparent and explainable ML and robust security measures. The project's success could significantly impact public health management by improving response times, lowering the emergency congestions, reducing hospital stays, and maximizing resource utilization, with implications for broader medical applications beyond cardiology.**

Keywords—Machine Learning, Deep Learning, Explainable AI, E-health 5G, Artificial Intelligence, smart ambulances.

I. INTRODUCTION

The recent pandemic events have resulted in unprecedented demands on National Health Services, highlighting the critical need for innovation in healthcare delivery. "eHealth," a term introduced about 20 years ago, represents health practices supported by digital tools, specialized personnel, and effective communication between healthcare providers and patients. This concept extends to the ability to search, find, understand, evaluate, and apply information from electronic sources to resolve healthcare issues.

With the advancement of technologies like 5G (and the imminent arrival of 6G), and the renewed push towards Artificial Intelligence (AI) / Machine Learning (ML) applications across various fields, the eHealth approach has become increasingly appealing and can be integrated into conventional practices, significantly enhancing public health management. Network performance in eHealth scenarios, characterized as "mission-critical," is vital as it often determines the outcomes of life-saving interventions.

The widespread use of ML in medicine ranges from aiding radiographic image analysis for diagnosis, predicting clinical evolutions, to automatic reporting for medical review. A noteworthy application is AI-supported cardiac investigations using Electrocardiograms (ECG), a widely utilized, standardized and non-invasive test in cardiovascular medicine, demonstrating the beneficial impact of modern technologies.

One of the major challenges is the fact that most of the popular ML algorithms are 'black boxes', meaning that the calculations are hidden, this makes ML hard to implement in those mission critical applications because, even with a high performance and confidence, they would not be trustworthy. One of the major focuses of this proposition is to apply cutting-edge methodology to make the Deep Learning (DL) neural network as transparent as possible.

II. OBJECTIVES

The proposition aims to enhance early CVDs diagnosis [1], providing a DL algorithm to speed-up more accurate diagnosis in emergency situations. This involves the deployment of "smart" ambulances equipped with digital diagnostic devices connected with ultra-fast, low-latency 5G connections to medical facilities, that will process the data, transforming current intervention methods.

III. PROPOSED ACTIVITIES

The proposition should comprehend the following activities:

1. Identifying, collecting, digitalizing, and correlating necessary medical data that could be obtained during emergencies for analysis, prognosis, and recommendations.
2. Creating digital historical archives to serve as databases for AI mechanisms.
3. Investigating controlled access solutions to data that respect privacy and de-identification requirements.
4. Study, development and implementation of DL algorithms for transparent and explainable diagnostic formulation.
5. Developing user interface for data visualization and interaction with DL algorithms.
6. Developing a comprehensive 5G solution to provide a high-capacity, low-latency connection to the smart ambulance.

The proposed use case poses several technical challenges and leverages cutting-edge technologies:

- The service covers a geographical dimension, therefore from the point of view of network connectivity (5G), the "network slice" is end-to-end and includes both the radio access part and the network infrastructure part in the same geographic area.
- Access to the patient's medical history must take place in a controlled manner, respect the authorization and traceability criteria of who accessed it and when, and respect for the right to privacy according to current regulations. For this purpose, a service infrastructure must be created to allow the various procedures for insertion, access, deletion, updating, etc.

- Although the use of AI techniques to speed up and improve clinical analysis on tests such as ECG appears very promising, the creation of a quality database suitable for the creation of predictive models is one of the most critical and debated at the level of the global technical community. Appropriately labeling the data, engineering it, carrying out experiments to identify the characterizing elements, testing the different algorithms and the related optimization techniques, requires a substantial commitment. The involvement of the Italian and European cardiac scientific community directly involved in the management of the project's target patients offers a broad involvement of professionals in the sector and the databases of the respective cardiology centers.
- Another challenge of AI/ML algorithms as specified before is introduced by their 'black box' nature, designing the neural network to leverage new transparency and explainability techniques; that will make the algorithms more trustworthy for every user that would be either experienced or not with the medical data.

The proposed activities require medical approval, so experimentation is currently limited to technological aspects only.

IV. EXPERIMENTATION

For the artificial intelligence part (points 1, 2 and 4 of the activities hypothesized in the previous chapter) a first experiment is underway which uses a public database of over 20,000 12-lead ECGs (PTB-XL) [2]. The DL model performs analysis of the ECG signal. Input given above signal; the individual derivations are analyzed, first focusing on local information; those are called beats. Subsequently we move on to analyze the totality of the individual channels, i.e. the rhythm; finally the extracted information is concatenated and analyzed at a global level. At each stage described above, information is extracted from the model to provide transparency, interpretability and explainability [4] of the results by medical personnel (i.e., why a certain diagnosis is formulated). The proposed model is composed of a hybrid structure that merges both convolutional and recurrent neural layers, boosting the model's efficacy to extract both local and global information of the ECG signal [5]. Also, the model incorporates attention layers to provide insights into the decision-making process, ensuring the transparency for clinicians to understand and trust the model's predictions. This system is developed in Python, utilizing open-source libraries (Keras, Tensorflow) to construct a multi-layer neural network model, specifically designed to analyze 12-lead ECG signals [3]. The model would be called Transparent Multi-Focus Neural Network (TMF-Net) and should be paired with a comprehensive preprocessing sequence. TMF-Net with a comprehensive preprocessing sequence demonstrated high effectiveness, achieving a test accuracy of 0.894 and area under the curve (AUC) of 0.962. It outperformed several state-of-the-art models, showcasing its capability in handling multi-label ECG classification challenges. TMF-Net offers a robust and transparent solution for real-time and accurate ECG diagnosis, potentially assisting both specialists and non-specialists. Further research could expand its application across more diverse cardiac conditions and explore additional preprocessing techniques.

V. CONCLUSION AND POTENTIAL IMPACTS

As TMF-Net progresses, its adaptability to different types of ECG data and its performance in diverse clinical environments will be key areas of focus. Expanding the dataset and incorporating more cardiac conditions will improve its robustness and help in handling imbalanced data distributions, a common challenge in medical datasets. Future enhancements will likely also explore scalability, aiming to process larger datasets efficiently without a loss in performance. This will ensure that TMF-Net can be deployed in various healthcare settings, possibly extending beyond cardiology to other areas where ECG-like data is relevant, and the potential application of Generative AI (GENAI) to further enhance the system's capabilities. GENAI can contribute in several ways: Predictive Modeling, Enhanced Diagnostics, Real-Time Analytics, Anomaly Detection.
The applicability of Distributed Ledger Technology (DLT) will be investigated to ensure the integrity and availability of sensitive data, in addition to the confidentiality already considered to support privacy. In summary, TMF-Net not only advances the field of cardiovascular disease management but also serves as a model for future developments at the intersection of AI and healthcare, promoting an approach where advanced technology and patient-centered care coalesce effectively. A potential demonstrator could include an infrastructure for historical data, ML predictive models, and a dedicated 5G slice covering a specific hospital campus with smart ambulances and diagnostic devices connected. The project could significantly transform healthcare delivery, optimizing resource use, saving lives, and reducing hospital occupancy rates.

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