Summary

Machine learning describes a class of algorithms that can combine inputs for prediction and classification purposes. Deep learning is a class of machine learning methods based on artificial neural networks with representation learning that uses multiple layers to progressively extract higher-level features from raw input. These algorithms, which represent subsets of the artificial intelligence (AI), have recently shown impressive results in a variety of domains, especially in medicine. Biomedical data are complex and often misunderstood. Hence, machine learning techniques can be particularly suited to solving these problems.
This thesis addresses some of these issues, by using both shallow and deep neural networks.

The first application deals with cardiovascular diseases, which represent the leading cause of deaths in the world. Arterial Blood Pressure (ABP) is a vital parameter that should be properly monitored for the purposes of prevention. The goal of this work is the continuous measurement of ABP through a non-intrusive approach. The approach is based on a neural network output-error and deep learning techniques to estimate ABP, starting from photoplethysmogram (PPG) and electrocardiogram (ECG) signals. The ABP was predicted first using PPG only and then using both PPG and ECG. The results show that the use of the ECG resulted in improved performance for each proposed configuration. The most performing configuration was obtained with a ResNet followed by three LSTM layers. It is also proven to be compliant with the ANSI/AAMI/ ISO 81060- 2:2013 regulation for non-invasive ABP methods.

Another related problem is about the Short QT Syndrome (SQTS), an inherited cardiac ion channel disease linked with an increased risk of sudden cardiac death (SCD) in young and otherwise healthy individuals. Arrhythmic risk stratification is particularly challenging in asymptomatic subjects. AI-based electrocardiogram (ECG) analysis has never been applied to SCD risk stratification in patients with cardiac channelopathies. The purpose of this study is twofold: on one hand, digitize the ECG paper-based in order to preserve the history and evolution of patients without the risk of the paper degrading (also facilitating the implementation of algorithms considering the vision of data as signals); on the other hand to analyse ECG features from SQTS patients with the aid of an AI system to evaluate its ability to discriminate between subjects with and without documented life-threatening arrhythmic events. The analysis of ECG features from SQTS patients with the aid of neural networks shows promising results in terms of discriminating between subjects with and without documented arrhythmic events (100 % negative predictive value). This could pave the way to a refined ECG-

based risk stratification in this group of patients, potentially helping in saving the lives of young and otherwise healthy individuals.

This thesis also takes into considerations a completely different, but still very challenging medical problem: when nanomaterials are used in this field (bio-sensor, drug-delivery, etc.), their production through the electrospinning process requires careful inspection of the nano material, to ensure that no structural defects are created. The presence of anomalies prevents from the practical application of the electrospun nano-fibrous material in nanotechnology. A new classification system is proposed to distinguish homogeneous nanofibers (without anomalies) from non-homogeneous ones (with defects). Specifically, the image to be analysed are used as input for an unsupervised-supervised hybrid machine learning system. In the first stage, an automatic encoder (AE) is trained to generate code that represents the input image with a vector of relevant characteristics. Next, a multilayer perceptron (MLP) uses the extracted characteristics to classify images with non-homogeneous nanofibers (NH-NF) and with homogeneous nanofibers (H-NF). The resulting AE-MLP system has been shown to outperform other standard machine learning models, reporting a high rate of accuracy.

The last part of this work considers the current problem of Coronavirus disease, which is rapidly increasing, and contagions need to be kept under control to prevent their spread. Therefore, the development of algorithms for the diagnosis of COVID-19 is an open research area. Many studies have shown that Chest X-Ray images can be used for COVID-19 testing. In this work, a deep transfer learning technique is used to classify infected patients. Experimental results reveal that the proposed deep transfer learning-based COVID-19 classification model provides efficient outcomes compared to other supervised learning models. In particular, the Vision Transformer achieved excellent performance with high test accuracy.
All the results obtained by the proposed neural models are better than the traditional approaches. This consideration justifies their use and paves the way to new possible applications in the medical domain.