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XXXV Cycle

Deep Learning Techniques for Automated Diagnosis Through Medical Image Analysis

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Research context and motivation

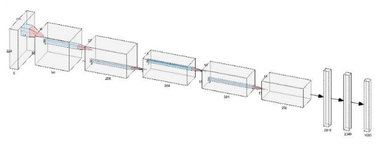
- Clinical diagnosis is a key element to identify any health issue and act **on time** in critical cases. It can be a difficult task even for expert physicians, especially when dealing with rare diseases.
- Artificial Intelligence can assist experts in assessing patients' condition, and can potentially catch details hindered to human perception.
- Aside from the application of Deep Neural Networks to medical images generally used for diagnostic purposes (e.g.: X-ray, epidermal nevus pictures), it can be shown that the very same techniques are also viable to analyze visual representations of signals, as for the case of scanned images of ECG charts.

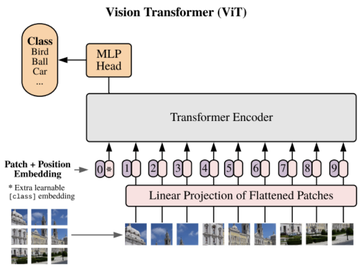
Addressed research questions/problems

- Identification of specific diseases from different types of clinical data can be rather challenging. This can be due to several reasons, most commonly:
  - The disease under investigation does not show evident signs, marks, nor does it provoke any relevant symptoms
  - It requires a deep assessment performed by experts with many years of experience
  - In some suspect cases it can be necessary to give patients specific drugs in order to have clearer disease signs show up
  - Subtle signs can often escape the expert's attention, leading to **misdiagnosis** and **wrong decisions**
  - Data is often **insufficient**, due to the distribution of the disease over population (e.g.: rare diseases)
- When dealing with rare heart syndromes, the vast majority of clinical archives mostly hold scanned copies of ECG charts. These images usually offer **very little data** to work with, and often exhibit **very poor quality**.
- Many researchers are developing methods to improve image quality and/or extract numeric signals from it, but this process is extremely **complicated** and **time-consuming**.

Novel contributions

- The novel Vision Transformer deep neural network architecture (ViT) has been successfully applied to identify many types of diseases by investigating clinical images over several medical fields (COVID-19, melanoma, Brugada syndrome, Short QT syndrome). This model has reached remarkable levels of accuracy and specificity even on very small datasets. Performance has been assessed against Convolutional Neural Networks (CNNs), which represent the most commonly used deep neural networks for image analysis.
- The Vision Transformer has largely outperformed CNN architectures on all given applications, all the while removing the need for image preprocessing.
- Sudden Cardiac Death (SCD) events caused by very rare heart disorders have been correctly identified by the neural architecture by analyzing a small number of low-quality scanned images of ECG charts.
- An insight into the information carried by clinical images can be gained by exploiting the Transformer's **attention maps**.





Submitted and published works

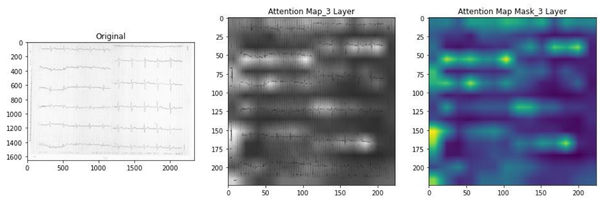
- Dichio, G., Putame, G., Terzini, M., Cannata, S., Costa, P., Pasero, E., and Audenino, A., "*Internal Fixation of Femur Fractures: A New Wireless Electromechanical Dynamization System*", Seventh National Congress of Bioengineering, Trieste (ITA), 2021. ISSN 2724-2129
- Cannata, S., Paviglianiti, A., Pasero, E., Cirrincione, G., and Cirrincione, M., "*Deep Learning Algorithms for Automatic COVID-19 Detection on Chest X-Ray Images*", submitted to IEEE Access
- Gaita, F., Giustetto, C., Pasero, E., Cannata, S., and Randazzo, V., "*A neural network model to predict life-threatening arrhythmic events in patients with Short QT syndrome based on ECG features*", submitted to Sensors

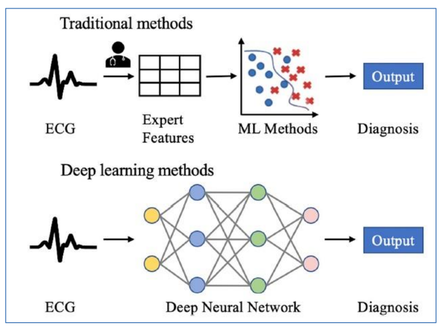
Adopted methodologies

- The Vision Transformer divides an image into equally-sized patches and evaluates the relationships among patches by means of the **self-attention** mechanism. This raises awareness about the global **context** of the picture, thus **eliminating** the need for **manual feature extraction**.
- All neural models (both ViT and CNNs) were deployed by fine-tuning networks that were pretrained on the ImageNet21k image dataset. This allowed to drastically reduce training time and computational resources.
- To deal with small datasets, a few common techniques were applied (dataset balancing, k-fold cross-validation, data augmentation)
- Performance examples:
  - The Vision Transformer reached an accuracy of **99.3%** when detecting COVID-19 on chest X-ray images, whereas the best performing CNN architecture, ResNet50, stopped at about 86%.
  - Patients with Brugada syndrome who suffered from SCDs were identified with an accuracy of **93.3%**.
  - Melanoma was correctly distinguished from benign skin tumor and seborrheic keratosis with a final accuracy of **83%**.

Future work

- Reaching the highest level of confidence when making clinical decisions is crucial; further testing on different, larger datasets must be carried.
- Artificially increase available data by means of specific neural models (e.g.: GANs, VAEs)
- The neural network architecture could be improved (e.g.: CNN + ViT hybrid).
- Final research goals include:
  - Gathering **deeper knowledge** about the investigated diseases
  - Attempting to **predict fatal events**





Other projects

- PulsECG – A noninvasive, unobtrusive wearable device for continuous arterial blood pressure monitoring
- WDPlate – A new wireless electromechanical dynamization system for internal fixation of femur fractures (in cooperation with PolitoBIOMed Lab and Intrauma s.r.l.)

List of attended classes

- 01UMNRV – Advanced deep Learning (didattica di eccellenza) (15/6/21, 6 CFU)
- 01UJBRV – Adversarial training of neural networks (1/7/20, 3 CFU)
- 02LWHRV – Communication (26/12/19, 1 CFU)
- 01PJMRV – Etica informatica (4/5/20, 4 CFU)
- 01UIXRV – Laboratory of wireless power transfer for electric vehicles (24/1/20, 2 CFU)
- 01UNVRV – Navigating the hiring process: CV, tests, interview (10/11/20, 1 CFU)
- 01RGBRV – Optimization methods for engineering problems (15/6/20, 6 CFU)
- 01SFURV – Programmazione scientifica avanzata in matlab (29/6/20, 4 CFU)
- 01RISRV – Public speaking (1/1/20, 1 CFU)
- 01SYBRV – Research integrity (8/1/20, 1 CFU)
- 01SWQRV – Responsible research and innovation, the impact on societal challenges (11/1/20, 1 CFU)
- 01QEZRV – Sviluppo e gestione di sistemi di acquisizione dati (24/8/20, 5 CFU)
- 02RHORV – The new Internet Society: entering the black-box of digital innovation (9/11/20, 1 CFU)
- 01UNXRV – Thinking out of the box (10/11/20, 1 CFU)
- 01SWPRV – Time management (23/11/20, 1 CFU)