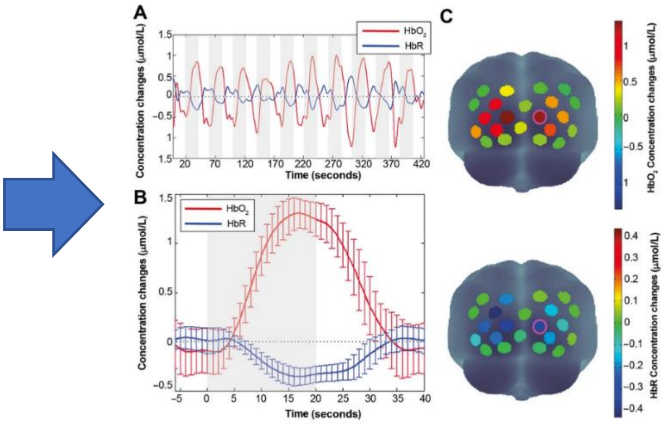
EXPLAINABLE ARTIFICIAL INTELLIGENCE FOR PHYSIOLOGICAL SIGNAL ANALYSIS



THE CHALLENGE

Can artificial intelligence recognize the intentions, emotional and/or pathological state of subjects by analyzing some of their physiological data? Can this recognition be validated by an expert in order to include it in medical decision-making processes and improve patients' lives?

https://www.youtube.com/watch?v=26YvPSKKtdc

EXplainable Artificial Intelligence (XAI) supports the algorithm's prediction with explanations of its internal model so that domain experts (e.g., physicians) can validate them and include them in decision-making processes. This step is critical because the European GDPR explicitly requires that an A.I. system be interpretable in order to be used in the medical domain. XAI can provide several forms of explanation, for example:

1. Identify which part of the inputs to the algorithm (e.g., part of the image, concept, form of the time series, or column of the tabular data) are most relevant for recognizing one or the other class: in this case, the algorithm's decision is validated if the physician would have considered the same elements to reach the same algorithm conclusion. This technology is accessible through both Python libraries (e.g., SHAP, sklearn, TCAV) and methods to be generated "from scratch".
2. Identify similar/dissimilar examples for the algorithm with respect to a classified example: in this case, the algorithm's decision is validated if the examples (or counterexamples) identified are consistent with the classification that the physician would have made. This technology is accessible either through Python libraries (e.g., Carla, DiCE) or through methods to be generated "from scratch" from heuristics or KNN approaches.

THE CASE STUDY

Electroencephalography (EEG) and functional Near Infrared Spectroscopy (fNIRS) are among the most widely used physiological signals to study current brain activity and function (e.g., the subject is thinking about moving a hand) or his or her state (e.g., healthy or affected by brain disease). Compared to other tools, such as MRI or magneto-encephalography, EEG and fNIRS present a better trade-off between temporal and spatial resolution (ability to measure the activity of rather small regions almost in real-time), coupled with the possibility of having wearable sensors and thus more easily usable in different contexts, as well as an extremely lower cost. In order to mitigate the noise present in these signals, it is possible to couple them with other sources of information, namely physiological signals such as heartbeat (ECG), skin conductivity (sweating) etc.

Specifically, the data analysis can address:

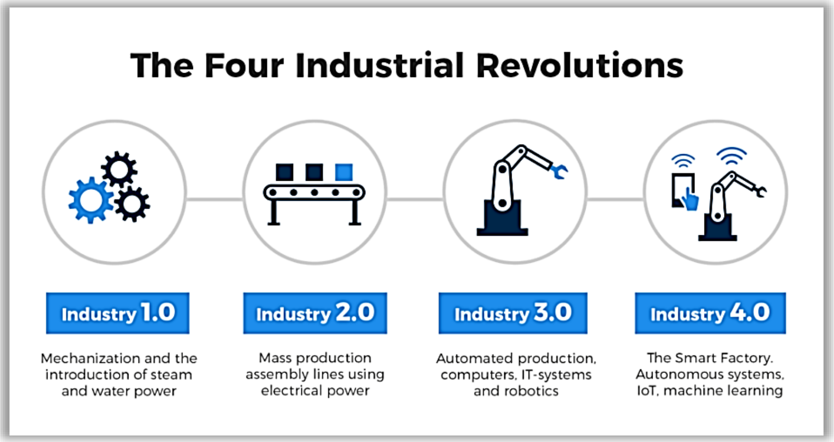
1. EEG and ECG for sleep quality monitoring. AI model explanations are easy to validate on this case study because of the extensive domain knowledge in the scientific literature. This data is available in time series or spectrogram format.
2. Emotions felt in a virtual reality experience or subjected to precise audio visual stimuli (e.g., scary images). This data is available either as a series or tabular data.
3. Data taken from motion and pressure sensors on the sole, obtained from sensorized shoes, of healthy people and/or those with early-stage mobility problems. This data WILL BE available as both series and tabular data.

THE THESIS

The thesis can be organized together with the correlators according to the interests of the undergraduate student, going to combine approaches from one of the XAI families and a case study from among those listed. The proposed theses are in collaboration with:

- Neuro-Cardiovascular Intelligence Lab of the Centro Piaggio dell'Università di Pisa, in the framework of the European project EXPERIENCE, which aims to recognize and reproduce emotions in a virtual reality environment, as well as to support AI-based diagnosis of pathological conditions.
- PNRR - Partenariato Esteso - "FAIR - Future Artificial Intelligence Research, Human-centered AI", funded by the European Commission under the NextGeneration EU programme.
- Dept. of Electrical Engineering, KU Leuven, Belgium

EXPLAINABLE ARTIFICIAL INTELLIGENCE FOR INDUSTRY 4.0



THE CHALLENGE

Can artificial intelligence predict the failure state of a component just before it occurs? Can artificial intelligence indicate or recognize the quality of a product currently being manufactured just based on the parameters of the manufacturing process? Can this prediction be deemed reliable by an expert in order to include it in industrial decision-making processes and save a huge waste of money?

https://www.youtube.com/watch?v=2_o1SDy6__U

The eXplainable Artificial Intelligence (XAI) supports the algorithm's prediction with explanations of its internal model so that domain experts (e.g., engineers in a factory) can validate them for inclusion in decision-making processes. This step is critical because in the absence of the reliability of the prediction it will never really be considered. The XAI can provide several forms of explanation aimed at making people understand the motivations inherent in the model's prediction and then validate them, for example:

1. Identifying which part of the inputs to the algorithm (e.g., part of the image, concept, time series shape, or tabular data column) are most relevant to recognize one or the other class: in this case the algorithm's decision is validated as to whether the physician would have considered the same elements to reach the same algorithm conclusion. This technology is accessible through both Python libraries (e.g., SHAP, sklearn, TCAV) and methods to be generated "from scratch."
2. Identify similar/dissimilar examples for the algorithm with respect to a classified example: in this case, the algorithm's decision is validated if the examples (or counterexamples) identified are consistent with the classification that the technical expert in the industry would have made. This technology is accessible through both Python libraries (e.g., Carla, DiCE) and methods to be generated "from scratch" from heuristics or KNN approaches.

THE CASE STUDY

More and more industrial machinery is being enriched with sensor technology and IOT connection. This makes it possible to monitor their operation constantly and comprehensively: for example, it is possible to cross-reference the industrial settings chosen to process a given product (e.g., the set speed of an unwinder in a paper process) with measurements taken in real time during processing (e.g., the temperature of a bearing or the consumption of a motor). This information can be processed by the latest deep approaches (if analyzed directly) or by shallow machine learning approaches (if features are extracted from signals).

Specifically, the data analysis can address:

1. Prediction of the remaining useful life of industrial bearings starting from time series analysis of temperature and vibration as they approach failure. This data is available in time series format or tabular data.
2. Recognition of the quality of paper output from an industrial production process starting from the processing setting and measurements (e.g., roller pressure) taken during the process. This data is available in tabular format.
3. Setting, motion and vibration data taken from elevators to monitor their maintenance status. This data WILL be available in time series format or tabular data.

THE THESIS

The thesis can be organized together with the correlators according to the interests of the undergraduate student, going to combine approaches from one of the XAI families and a case study from among those listed. The proposed theses are in collaboration with:

- PNRR - Partenariato Esteso - "FAIR - Future Artificial Intelligence Research, Human-centered AI", funded by the European Commission under the NextGeneration EU programme.
- National Center for Sustainable Mobility MOST/Spoke10, funded by the Italian Ministry of University and Research in the framemwork of the National Recovery and Resilience Plan;
- the Italian Ministry of Education and Research (MUR) in the framework of the FoReLab project (Departments of Excellence)