AIWean

Patient-specific prediction of successful ventilator weaning through massive signal processing and machine learning

LTSI INSERM U 1099
LATIM – CHU Brest
LabSTICC

Context: Intensive Care Units

- The decision to **stop ventilatory support** (ventilator weaning) **in intensive care units (ICU)** is a complex task.
- Application of **population-based** guidelines often leads to **repeated failing weaning attempts** or complications due to a prolonged assisted mechanical ventilation.
- **Patient-specific** methods allowing for a personalized follow-up in this context are thus of major interest.
- The possibility of **acquiring and processing massive monitoring data** in ICU may help to **improve the prediction of successful weaning**.

Challenges

- Acquisition of intensive care monitoring data is a complex problem. Specific tools are needed.
- Monitoring data is noisy, multivariate, heterogeneous and time-dependent, thus difficult to process.
- Explainable ML methods are needed in this context.

Main objective

To **evaluate the feasibility** of a set of ICT tools and methods proposed by the project partners on massive ICU data processing to **predict successful weaning using patient-specific criteria**.

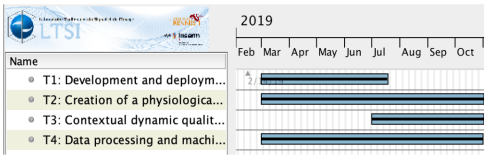
Project organization

Task 1 (LTSI): Development and deployment of a system for the continuous acquisition of physiological signal data from intensive care monitors.

Task 2 (LATIM): Creation of a physiological data warehouse of longitudinal cardiorespiratory signals from adult patients in ICU.

Task 3 (LabSTICC): Contextual dynamic quality assessment of the acquired data.

Task 4 (LTSI): Data processing and machine learning for the prediction of successful ventilator weaning.

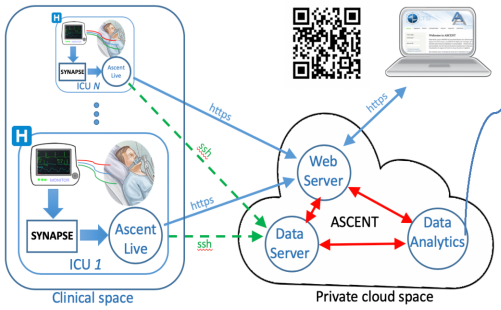


5 Permanent staff from partners were involved.
7 Internships of different levels (DUT, Eng., Masters) were proposed (4 in LTSI, 2 in LabSTICC, 1 LATIM-CHU Brest).

General architecture

AIWean relies on **two systems,** previously developed by LTSI, for the acquisition, management and processing of massive longitudinal data, that have been **customized for the specific objectives of this project**:

- **SYNAPSE** is an integrated system to continuously acquire signals from ICU monitors at the highest resolution, integrating local, embedded and original real-time signal processing methods.
- **ASCENT** is a private cloud-based system for the storage, transfer and centralized data analytics of longitudinal clinical data, acquired from multiple hospitals, in the context of clinical research protocols. This system provides state-of-the-art anonymization and security technologies, based on robust open-source projects, as well as traceability and quality management features.



Massive signal data acquisition

A new version of SYNAPSE (v3) was developed. It integrates specific requirements for adult cardiorespiratory monitoring and optimizes resources, allowing for the synchronous acquisition from a larger set of monitors/ patients per instance of SYNAPSE.

AIWean's data warehouse

Retrospective data (signals and detailed annotations) were acquired within the **REASTOC** clinical study, led by CHU of Brest, using SYNAPSEv1. These data were anonymized, structured and uploaded to ASCENT during the first 3 months of the AIWean project. The whole anonymized database (including annotations) was frozen at M5. It includes data from **524 patients, with each patient having a mean of 12 hours of continuous cardiorespiratory signals and the corresponding clinical annotations**.

Contextual quality estimation

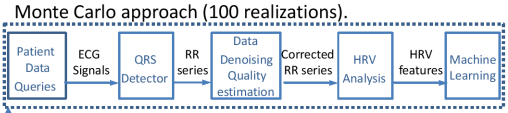
Two methods were developed to **estimate the usability of noisy signals**. Firstly, a **CNN** was designed to identify and characterize noise, as well as to estimate SNR. ROC AUC of 0.97 were obtained when applied to raw ECG segments of 48 individuals. Secondly, a **clustering** scheme was applied to estimate the impact of noise-characterizing features on cardiac beat detection. This method was applied to noise features from all 524 patients of the **REASTOC** database. The obtained clusters open the way for the development of a noise context-based beat detector.

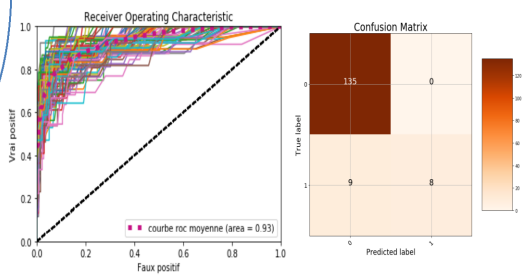
Data processing & ML

A specific cloud-based massive ECG processing workflow has been proposed for this project and integrated into the data analytics component of the ASCENT system.

Data Processing: ECG from all REASTOC patients were processed to i) detect each beat, ii) estimate quality and iii) extract 81 features per record with sufficient quality.

Machine Learning: A clinical feature related to ventilator weaning assessment (patient/ventilator asynchrony) was used as target of a Random Forest method, taking as input the extracted features. After feature optimization, K-fold learning and cross validation was applied within a Monte Carlo approach (100 realizations).





Main output of the project

- A new version of the **SYNAPSE system**, with a new GUI and integrating multi-monitor support for CHU of Brest.
- Improvements to the **ASCENT system** for the remote completion of recurrent electronic case report forms.
- Creation of a deidentified and **structured research database of 524 patients**, monitored in the Brest ICU, containing **continuous cardiorespiratory signals with a mean duration of 12 hours/patient and annotations of the main clinical markers**. These data have been uploaded and integrated into the ASCENT system.
- Feasibility of assessing three **contextual quality levels** for noisy ECG signals applying a convolutional network.
- **Data processing and machine learning methods** for predicting the main clinical markers of patient weaning using features extracted from the signals.
- **Potential marker for the prediction of patient - ventilator asynchronies** for the estimation of weaning response based on heart rate variability.

Conclusions

- We consider that the **feasibility has been validated**.
- Encouraging preliminary results from **524 patients** on **potential personalized markers for optimal weaning**.
- A step towards **individualized ventilator weaning:**
  - Improving the quality of life of ICU patients
  - Impact on health care costs (5-fold increase in costs of a ventilated patient WRT a non-ventilated one).
  - Potential integration into a DSS (SYNAPSE).
- Possible extension to other longitudinal or chronic pathologies such as the estimation of decompensations of chronic heart and lung diseases.