RÉPUBLIQUE FRANÇAISE
*Liberté*
*Égalité*
*Fraternité*

Inserm

La science pour la santé
From science to health

# L'intelligence artificielle à l'Inserm : Partenariats public-privé sur l'IA


Alfredo HERNANDEZ, DR Inserm

Responsable équipe SEPIA
LTSI – INSERM U1099 / Université de Rennes

# SEPIA Team - LTSI - INSERM U1099/Université de Rennes

**Research context:** Personalized diagnostics and treatments for cardio-respiratory pathologies

**Multidisciplinary team with 14 permanent staff:**

8 scientists with engineering background,
6 PUPH : 4 cardiologists, 2 neonatologists, 1 biologist

**Longstanding translational research strategy (from methods to the patient):**

**Methodological contributions motivated by clinical problems:**

Massive data processing, Mathematical Modeling, Machine Learning, AI

**Technical innovations:**

Development of prototype medical devices and systems

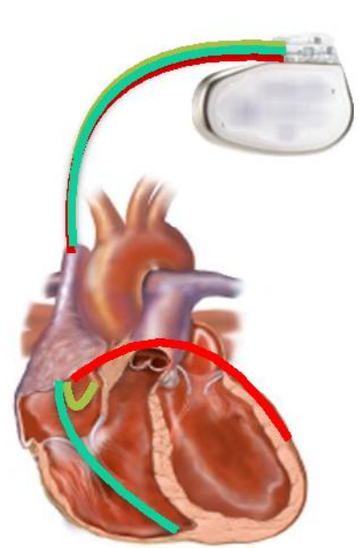
**Pre-clinical and clinical research:**

Evaluation of methods and devices

**Strong experience on intellectual property development and tech-transfer:**

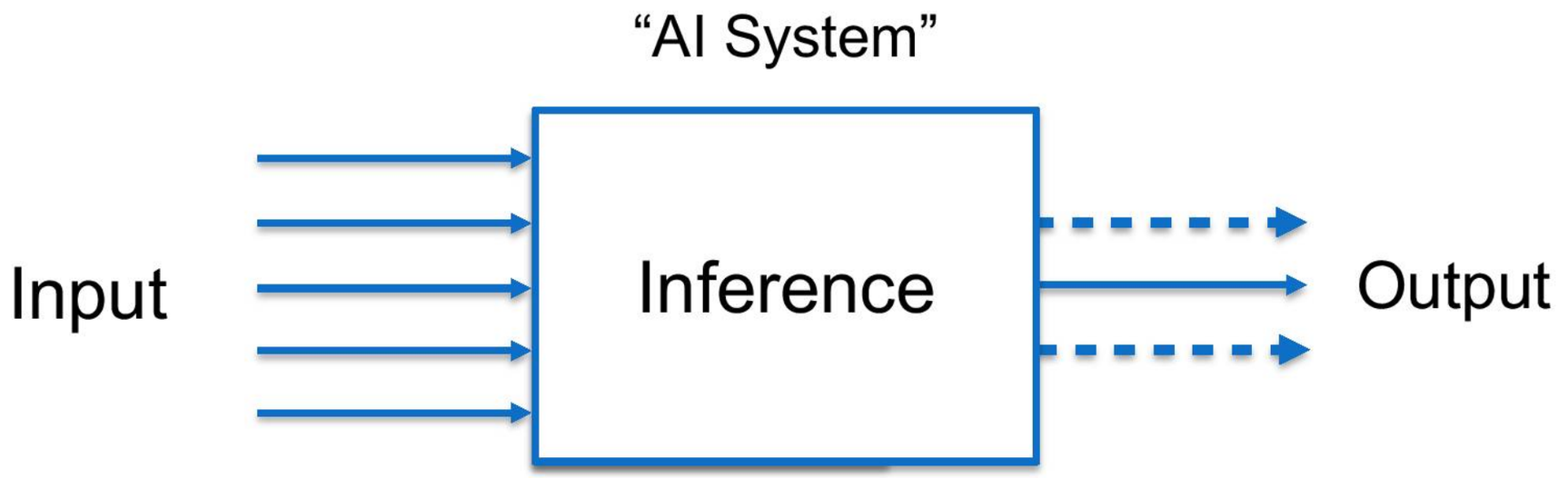
30+ patent families registered (60+ individual patents)
24 patent families transferred to or co-registered with the industry
Creation of 2 startups

A key element to perform this translational research: the creation of **« intelligent systems »**



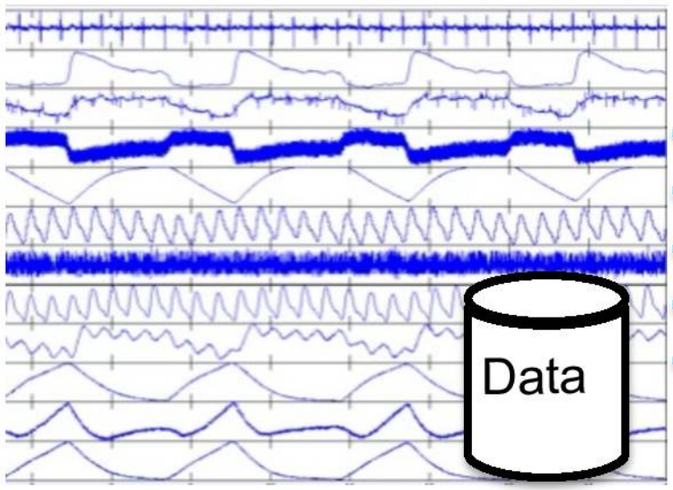
# Definition of an "AI System" according to EU 'AI Act' Art 3(1)

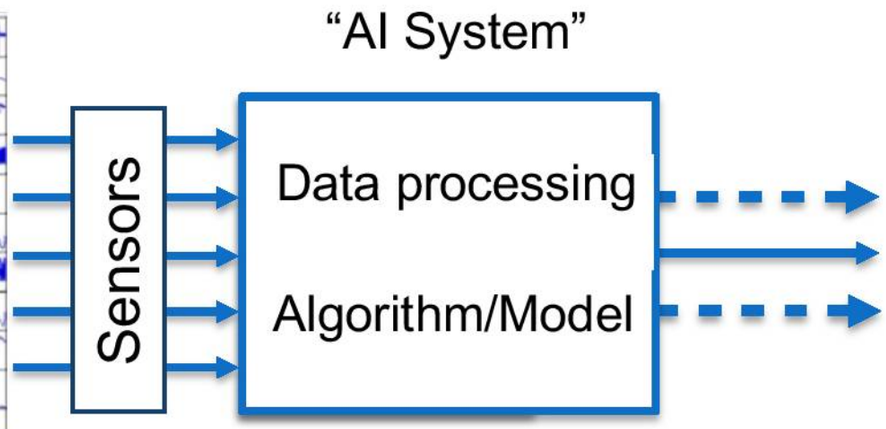
*"'AI system' means a **machine-based** system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, **infers, from the input** it receives, how to **generate outputs** such as predictions, content, recommendations, or decisions that can **influence physical or virtual environments**;"*




*Guidelines for the definition of an AI system Feb 2nd 2025*

# Examples of AI Systems in our research



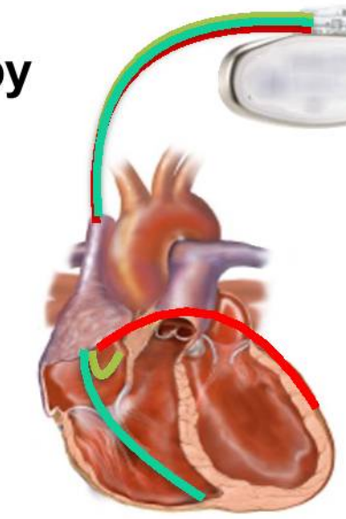




**Clinical decission support systems**

- **Early detection**
  Intelligent Alarms


- **Support for therapy personalization**

**Fully-autonomous systems**



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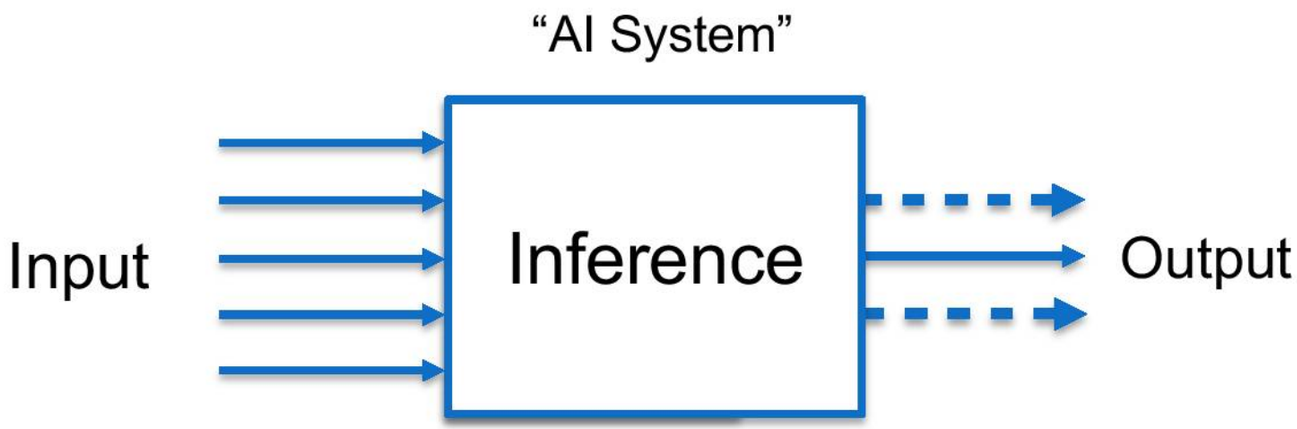
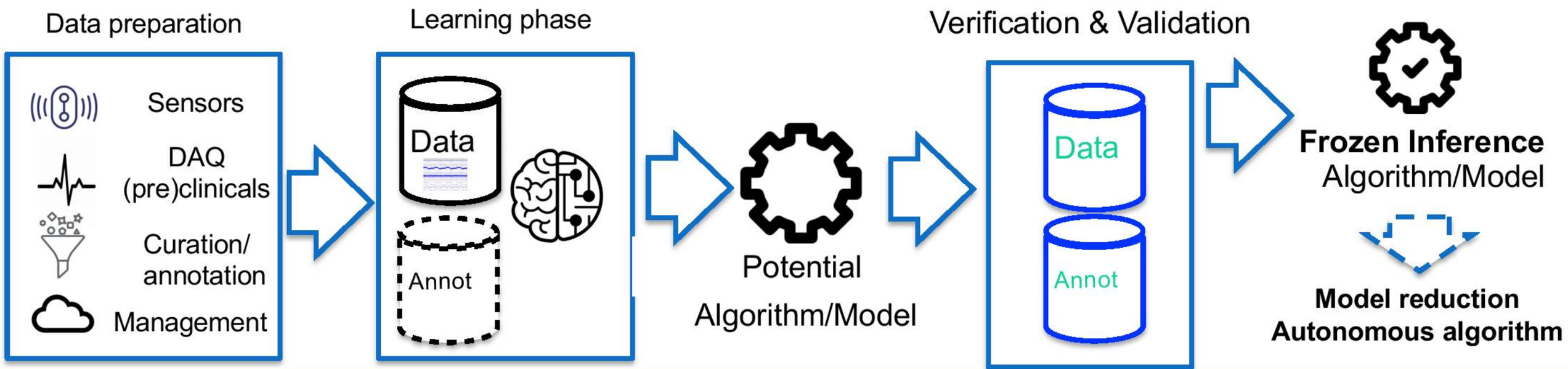
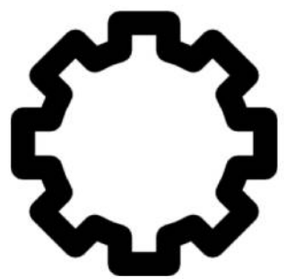


# Choosing the best model/AI formalism



There is **no "universal AI"** that will optimally solve all problems

The choice of the **best algorithm or model** formalism, **for a given problem**, has significant consequences in terms of:

- Interpretability, explainability, model transparency
- Model validation methods
- …
- Real-life acceptability and applicability of the system

# Different AI models with different properties

Data-driven
Problem-agnostic

Knowledge integration
Interpretability - Explainability

Knowledge-driven
Problem-specific

Data Intensive — Black box models — Gray box models — Less Data Intensive

Sub-Symbolic AI - No feature extraction phase

Symbolic AI (GOFAI)
Feature engineering

Knowledge-based models
Digital twins

**Foundation models**

Non interpretable

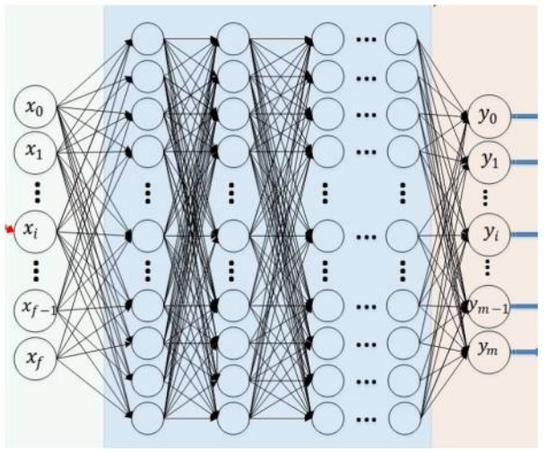
(Very) Limited interpretability

Indirect interpretability

Direct **Explainability**

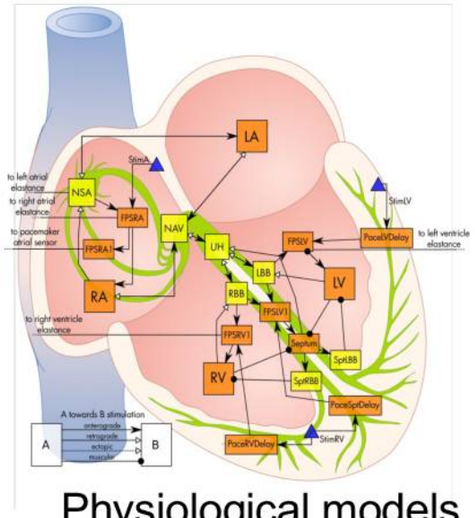
**Generative AI:**
**Generation of new content**
(text, image, music,…) or data based on statistical patterns it learns from existing data, **mimicking human-created content**

~600 Billion paramètres



i.e. Deep Learning

. . . .



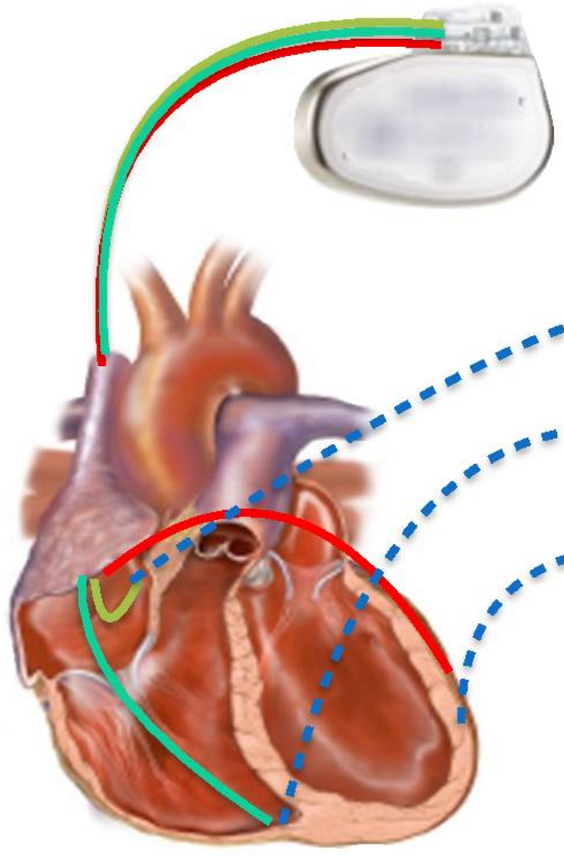

Physiological models

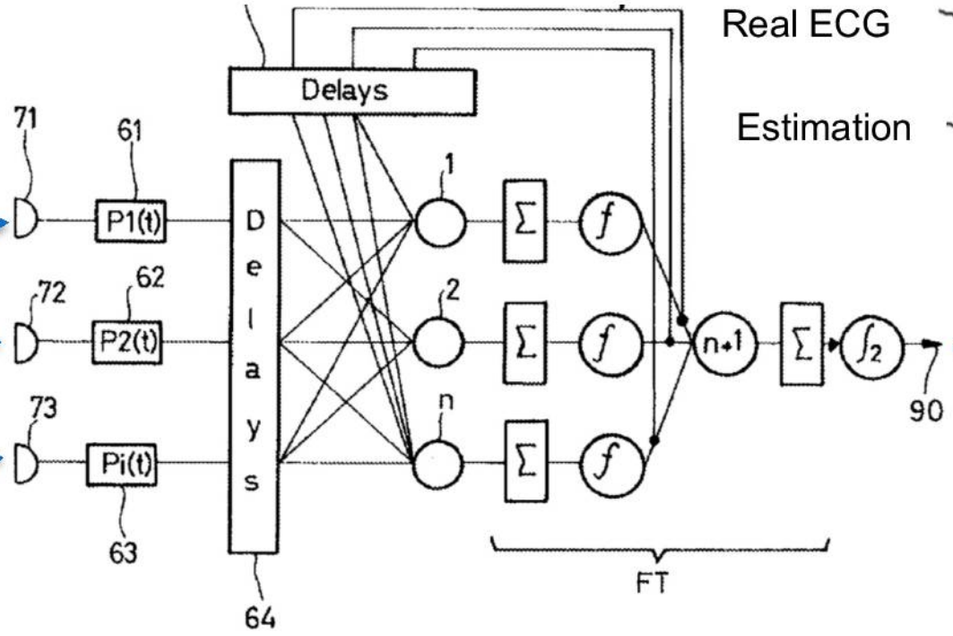
~ 1 - 10K paramètres

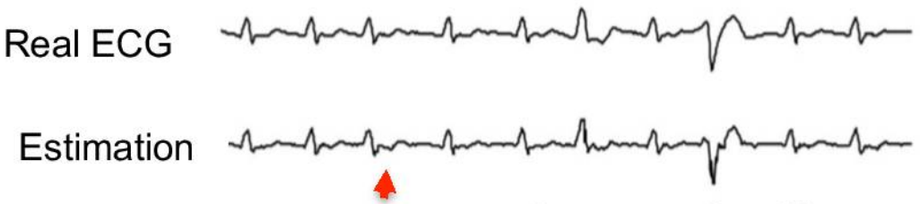
# Therapy personalization – Optimal cardiac stimulation

Light-weight (shallow) CNNs

Convolutional/recurrent neural networks






**2 patent families:**

US20080114257

US20100256511

**Clinical evaluation**

[IEEE TBME 2013]

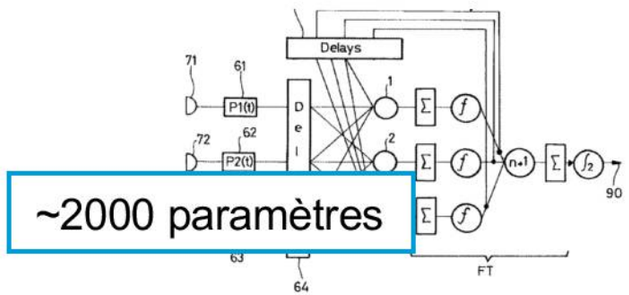
**Transfer to the industry : Sorin CRM**

Novel digital markers of the **cardiac electrical activity**
Useful for the **personalization of the stimulation therapy**
Lightweight CNN **that can be embedded into the device**

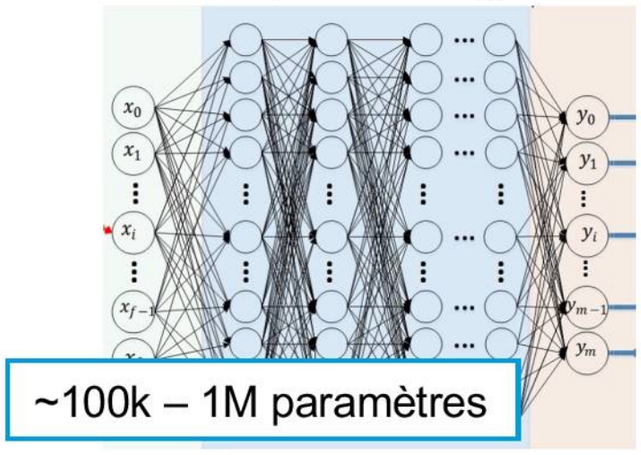
ADAPTER

# Current and recent projects exploiting connectionist models

Light-weight (shallow) CNNs

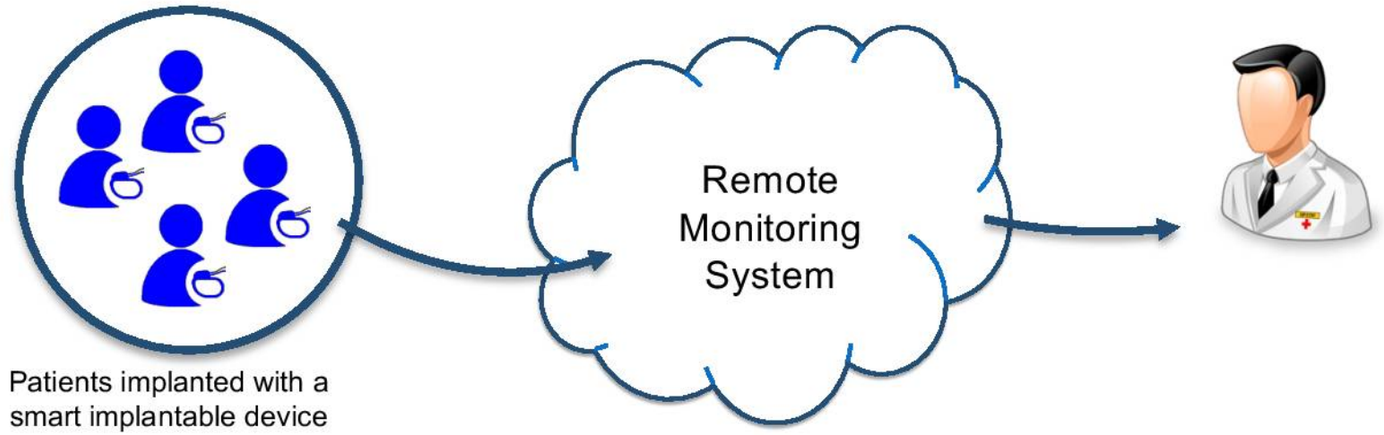



Deep Learning




## Current/recent projects based on Deep Learning:

- PPP with a major company in the **cardiac implant field**: Medtronic (2020-2023)




- Projects with french startups: i.e. SentinHealth **(EIT Health)**
- Purely academic: **PEPR Santé Numérique** « DIIP Heart »

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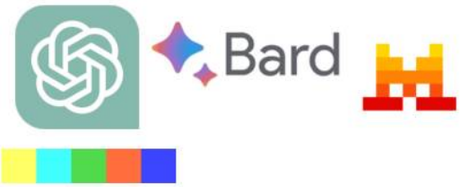
Direct **Explainability**



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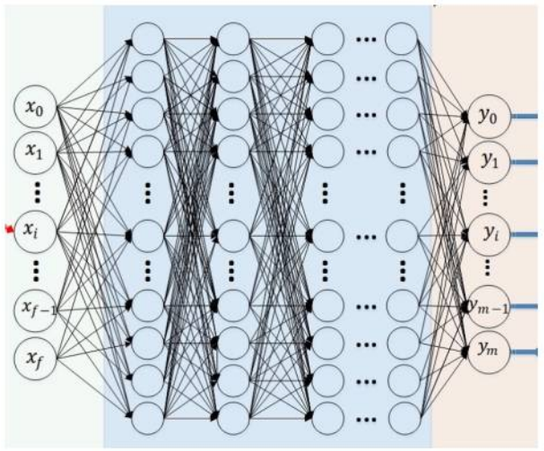
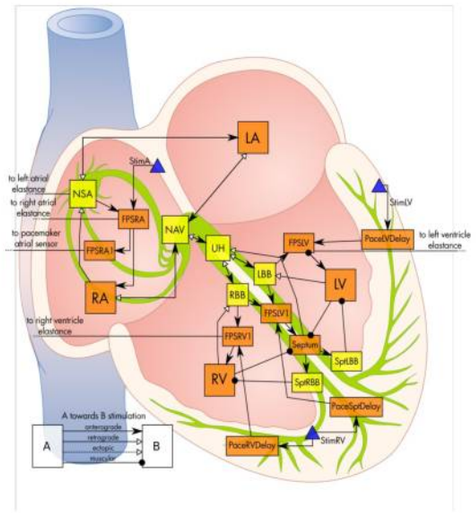



i.e. Deep Learning

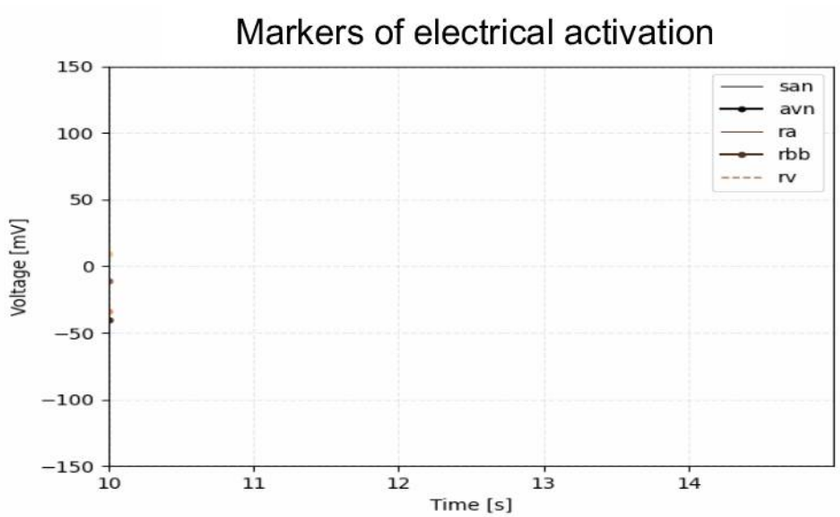
. . . .

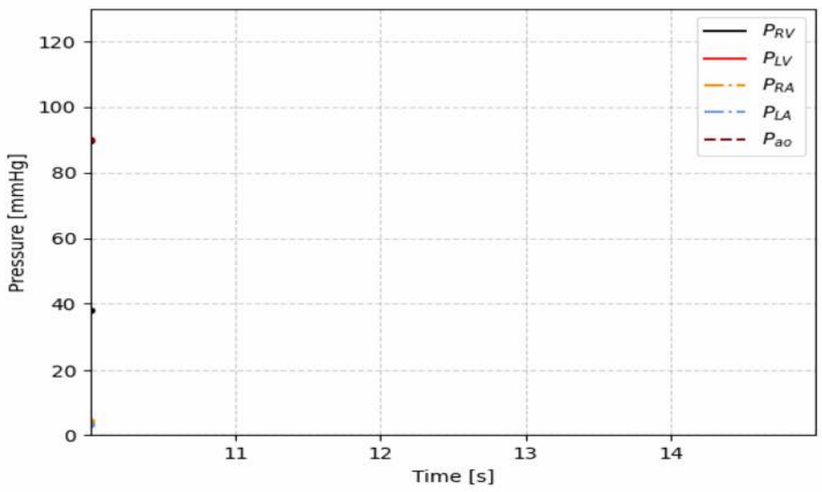


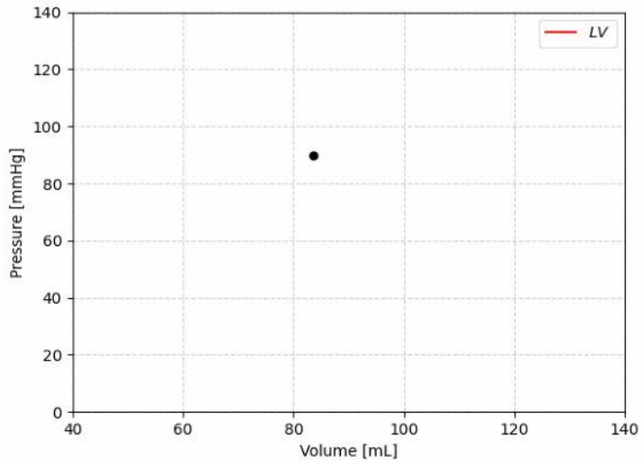

Physiological models

© A. Hernández

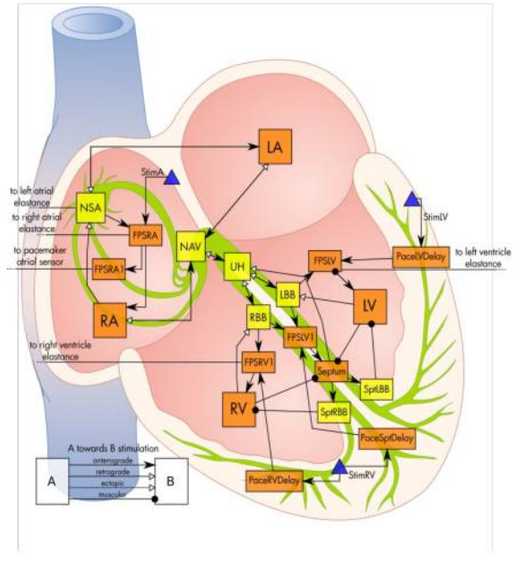
# Fully-explainable AI based on digital twins



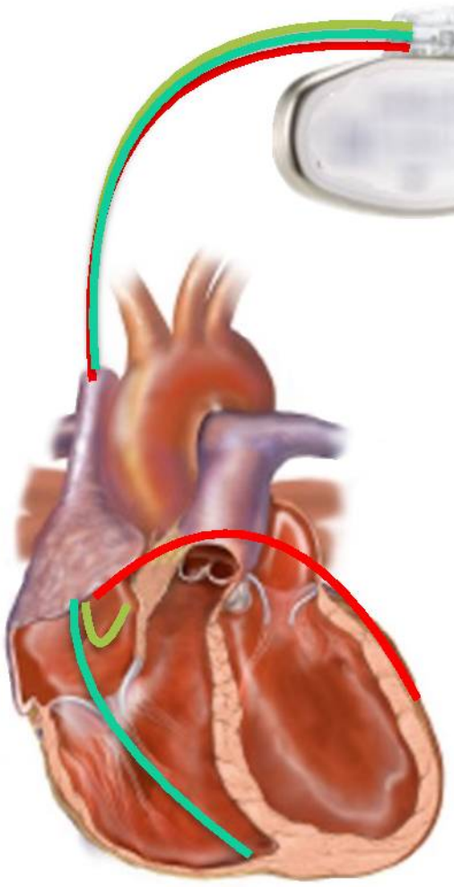



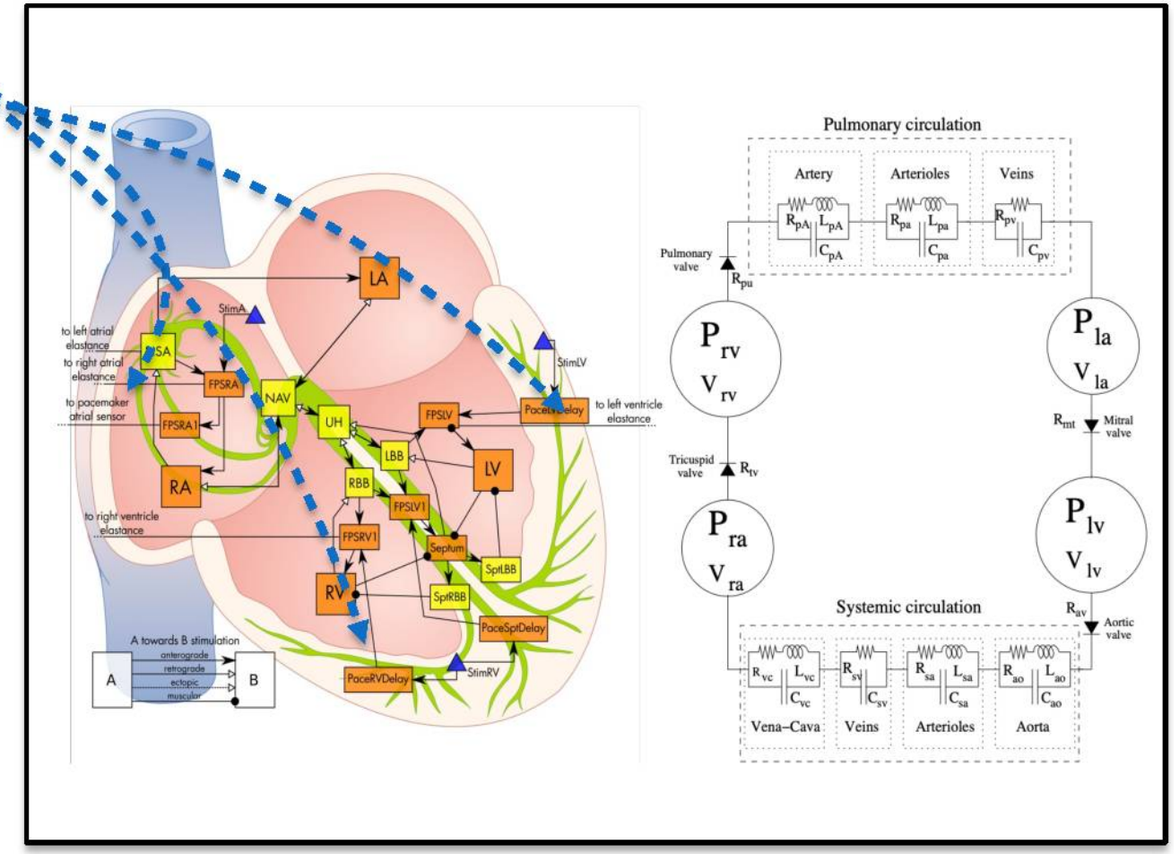

*Hernández et al. Model-based interpretation of cardiac beats. Artif. Int. Medicine. 2001*




- Creation of a set of multiresoultion cardiovascular models
- Explicit representation of anatomical and physiological functions
- Generation of realistic signals with its explanation
- Model personalization -> Digital Twins
- Virtual populations

# Therapy personalization through fully-explainable AI






**Original model-based reasoning methods**

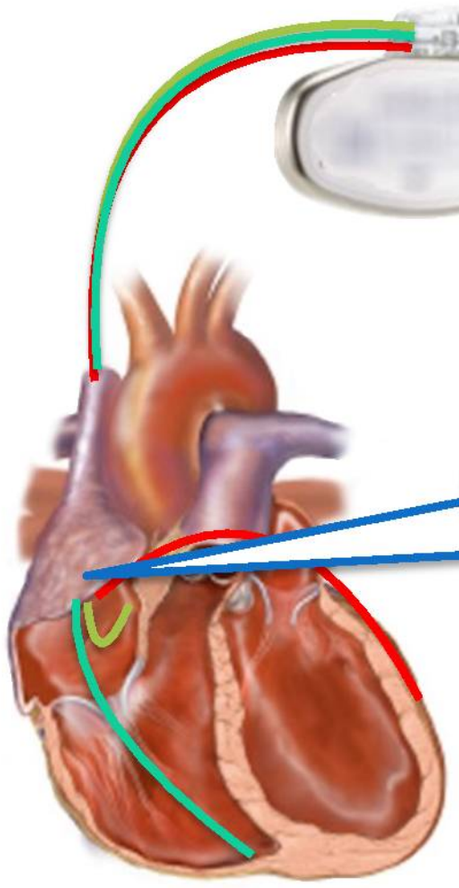
- Sensitivity analyses
- **Patient-specific** model parameter identification
- **Digital Twins** and generation of **”virtual populations”**

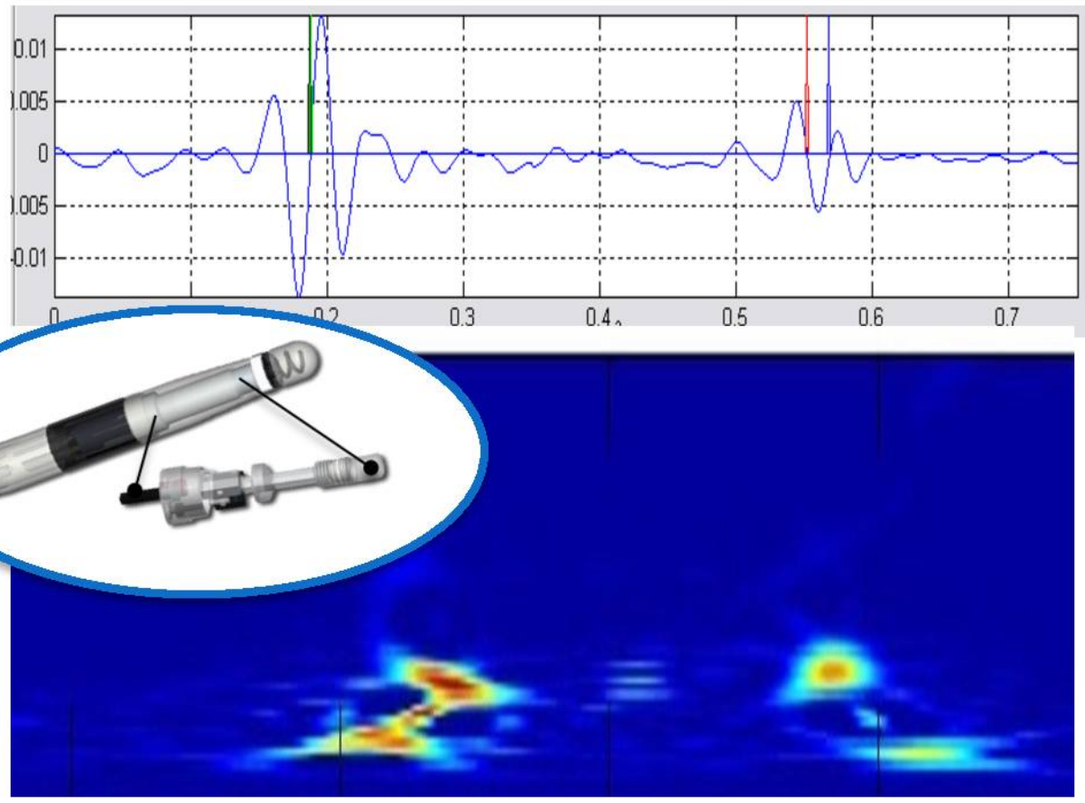
“Grey-box” or “transparent” methods (Explainable AI - XAI)
Explicit representation of the complex **electro-mechanical** interactions

ANR MICA & OptimHome

# Therapy personalization through fully-explainable AI

## Analysis of intracardiac acceleration






**1 patent family:**
US20090209875
**Clinical evaluation**
[Europace 2011]
[IEEE TBME 2014].

**Transferred to Sorin CRM**

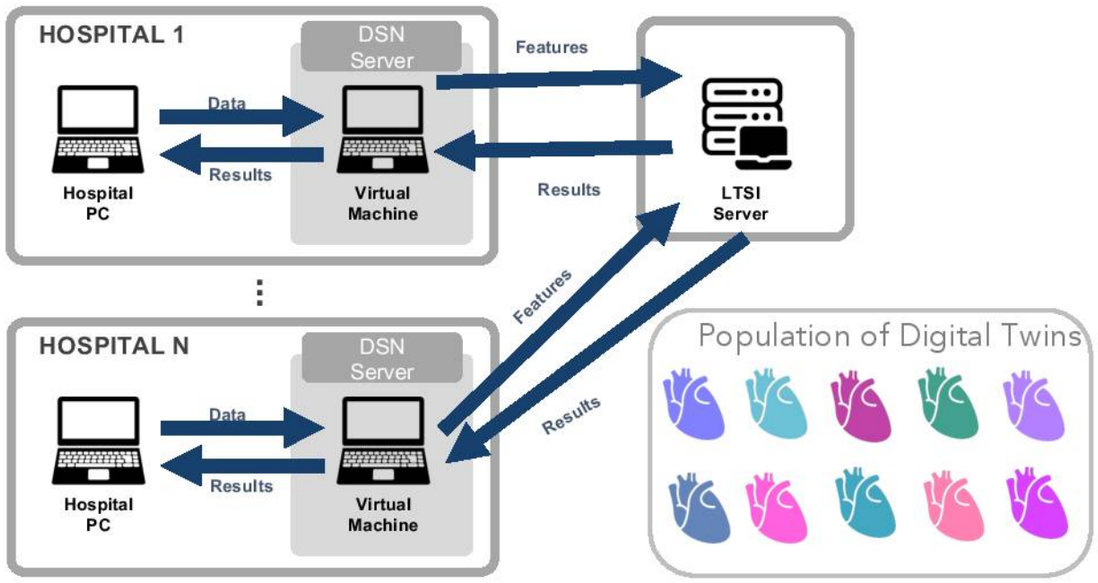
MICA & OptimHome

New digital markers of the **electro-mechanical cardiac function for therapy personalization.**

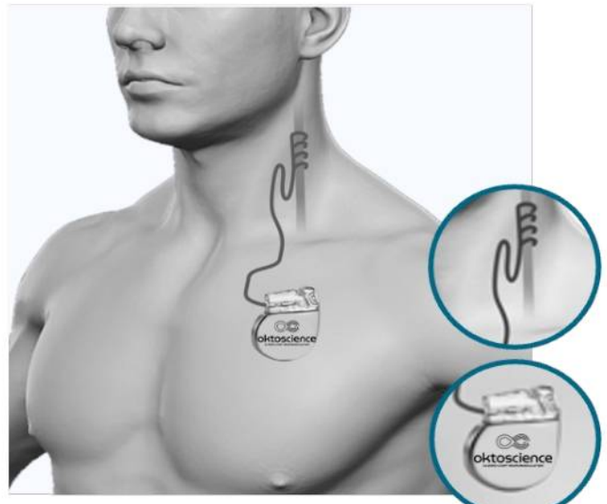
# Current projects exploiting AI and Digital Twins

## ANR-DGOS « Expert » (2023-2026):

Prospective inference evaluation of model-based methods for the prediction of CRT response




oktoscience
CLOSED-LOOP NEUROMODULATION



**7 patent families** all delivered in EU, WO, US

**16 main publications**

**Winners of BPI iLab 2024**

# Different AI models with different properties

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Interpretability - Explainability

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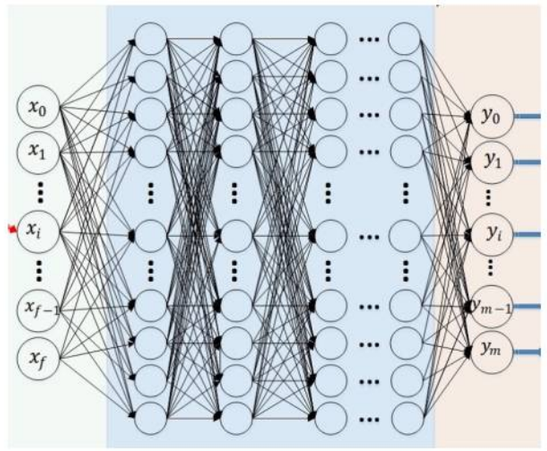
**Foundation models**

Non interpretable

(Very) Limited interpretability

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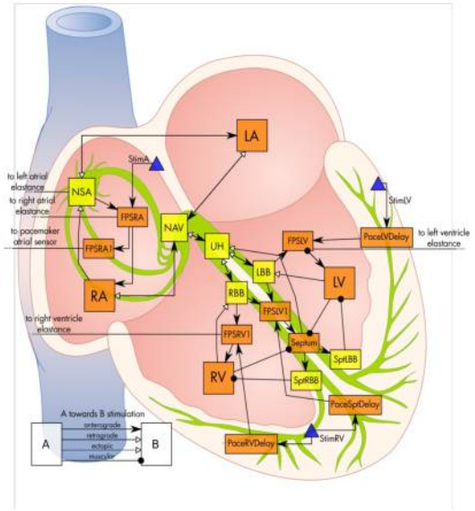


Physiological models

© A. Hernández

# Intelligent monitoring of preterm newborns

Digi-NewB

EU H2020 (2017 - 2022)

**Objective**: Early detection of risk events
(i.e. apnea-bradycardia)

**French National PHRC “Caress-Premi”**
**EU Project H2020 ”DigiNewB” (2017 - 2022)**

Multicenter, massive data acquisition:

- **Signal monitoring 24/7** (mean duration = 3 weeks)
- **>400 patients**, >3500 upload sessions, ~2 M files
- Equivalent of **> 25 years of continuous signals**.
- **Annotations** of the main clinical events

# Intelligent monitoring of preterm newborns

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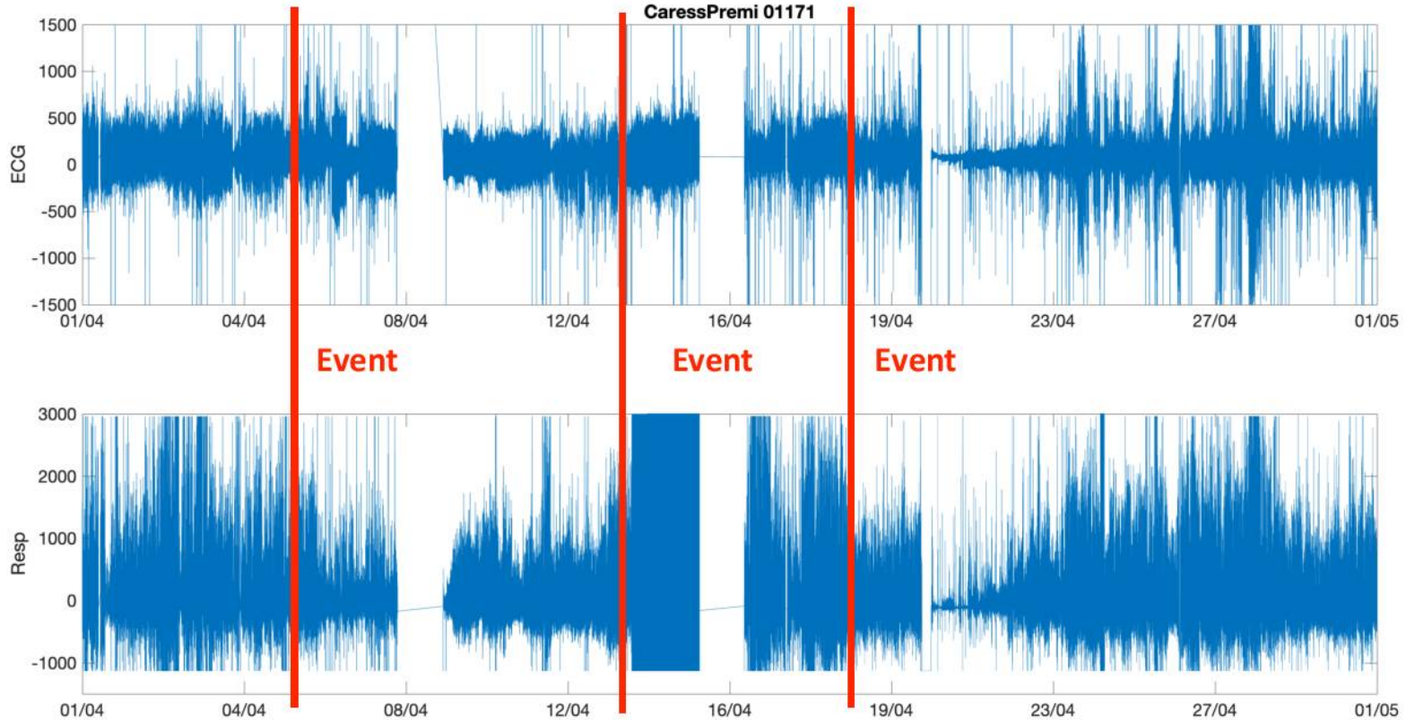


"Real-life" representative example: signals acquired during **1 month**

1.3E9 ECG samples. ~5M heartbeats.

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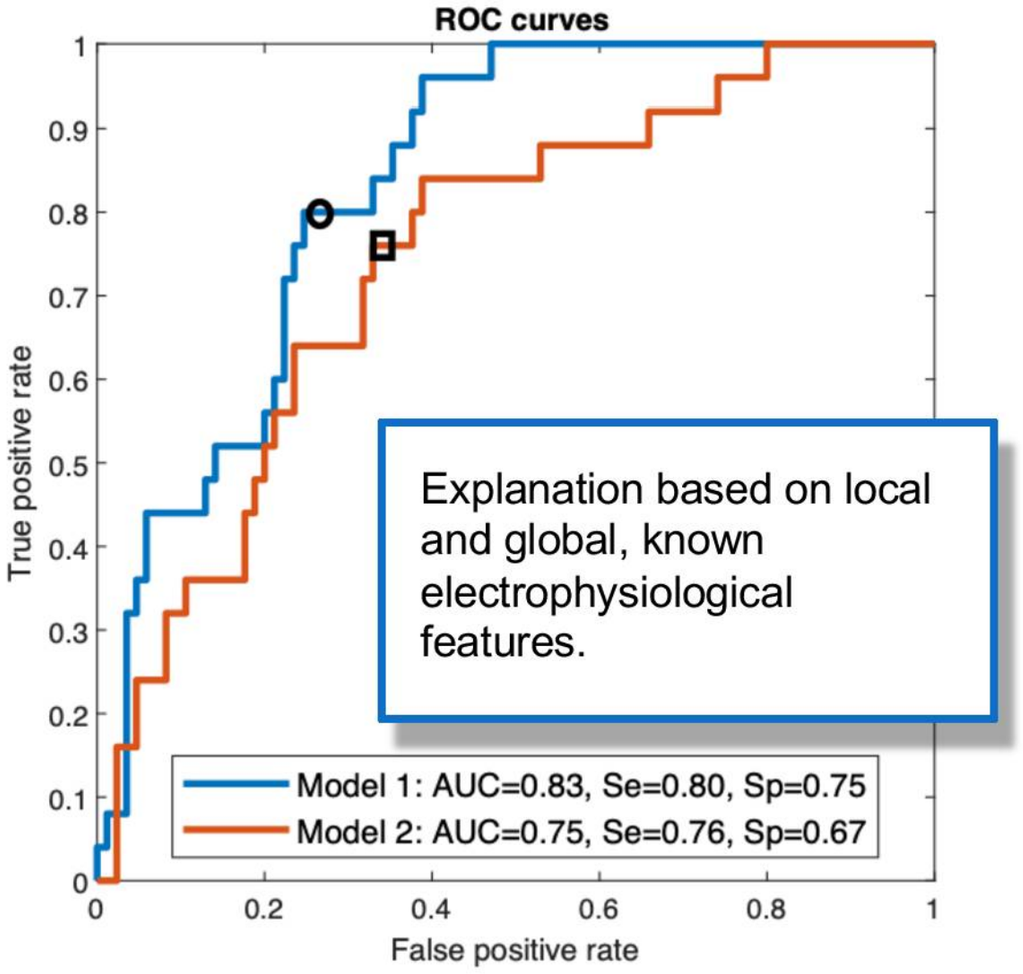
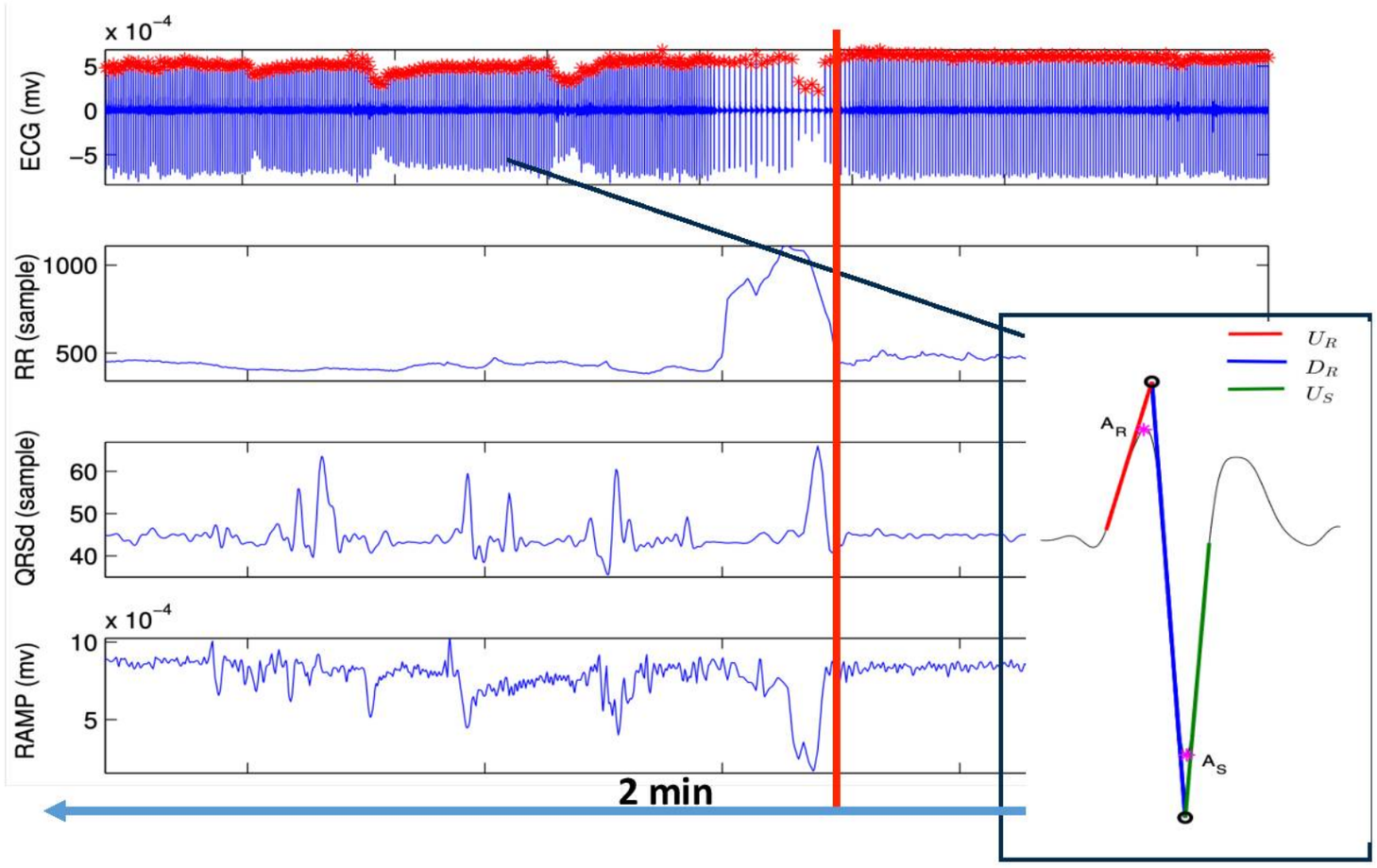



Explanation based on local and global, known electrophysiological features.

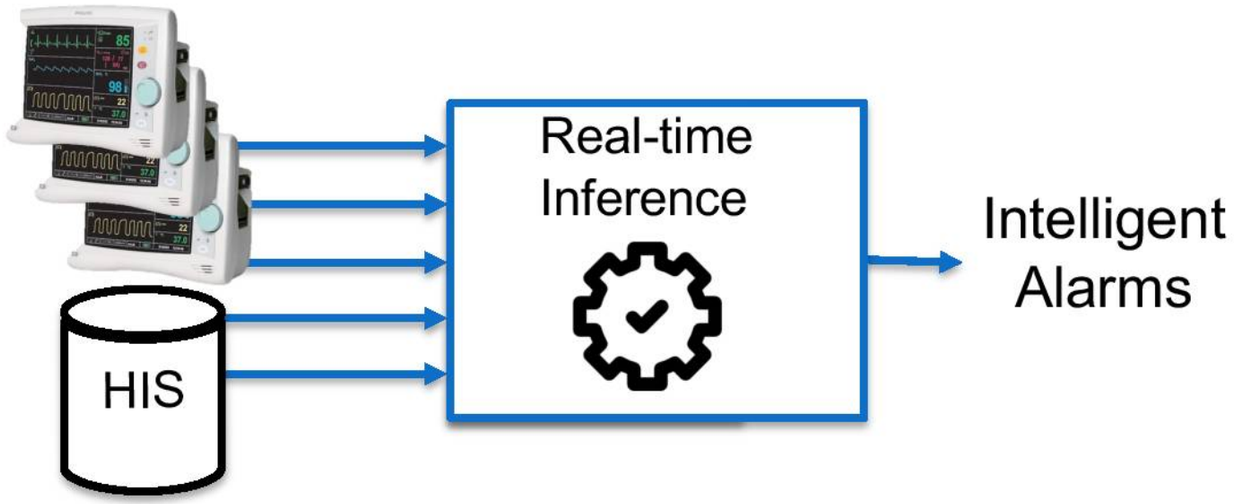
## Beat-to-beat interpretable **feature extraction**



# Current projects based on Signal Processing and AI

## XENIAH Project (2022-2025):

Explainable, on-the-edge application of intelligent monitoring systems




CHU Rennes

Quanta Computer Inc.

Pasithea

https://pasithea.health/


**8 patent families** all delivered in EU, WO, US

**9 main publications**

Created in January **2023**

Initial **seed funding** raised with NLC venture studio.

**BPI FTE in 2023**

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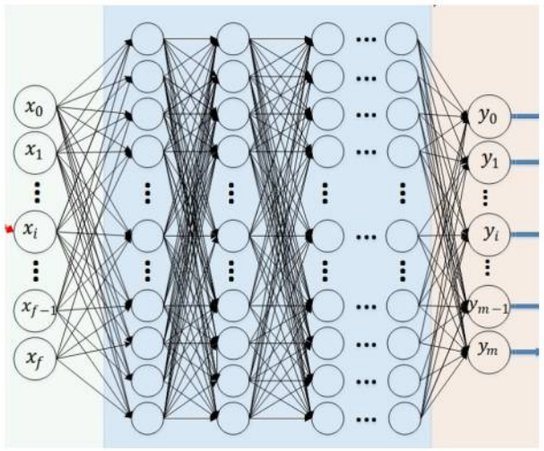



i.e. Deep Learning

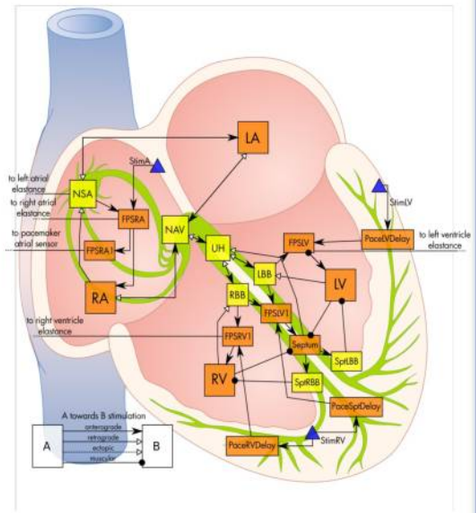
Symbolic AI (GOFAI)
Feature engineering

Indirect interpretability

Knowledge-based models
Digital twins

Direct **Explainability**

Hybrid AI methods




Physiological models

© A. Hernández

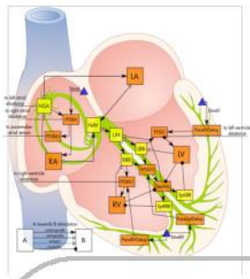
# Current projects based on Hybrid AI methods

SMASH HCM

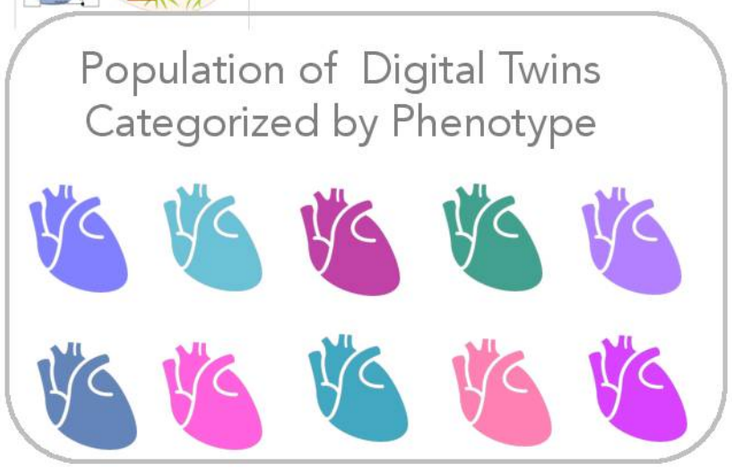
EU Horizon RIA 2023-27

**Objective**: Stratification, Management and Guidance of Hypertrophic Cardiomyopathy Patients using **Hybrid Digital Twin Solutions**

Industrial partners: Medtronic, InSilicoTrials, Pharmatics



\+ Machine Learning




PHARMATICS

MedAI®: predictive software integrated via an API for Pharma and MedTech

# Conclusions

- Inserm has a **valuable, longstanding, recognized know-how and experience on AI in healthcare,** leading to **real-life clinical applications**.
- A **huge added value** in the field
  - Multidisciplinary expertise
  - Continuum from basic research to (pre)clinical evaluation
  - Multiscale and multisource databases – novel clinical trials
- Collaborative research (public and public + private) is a key transformer in this complex domain
- Reaching maturity of the tech transfer ecosystem
  - Win-win projects with the private sector and creation of startups.
- Future is **plenty of opportunities** … but also, of **challenges to cope with**:
  - Attracting highly-trained staff in all concerned disciplines.
  - Further improve our innovation ecosystem – synergies with all involved actors.
  - Infrastructure

# Merci !

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