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CÔTE D'AZUR  3iA Côte d'Azur
Interdisciplinary Institute
for Artificial Intelligence

Comment faire apprendre la physiologie cardiaque à une intelligence artificielle ?

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Head of Multimodal Data Science - *IHU Liryc*

Co-founder of *inHEART & Therapixel*

01

Intelligence Artificielle

ARTIFICIAL INTELLIGENCE

IS NOT NEW

ARTIFICIAL INTELLIGENCE

Any technique which enables computers to mimic human behavior



MACHINE LEARNING

AI techniques that give computers the ability to learn without being explicitly programmed to do so



DEEP LEARNING

A subset of ML which make the computation of multi-layer neural networks feasible



1950's 1960's 1970's 1980's 1990's 2000's 2010s

ORACLE

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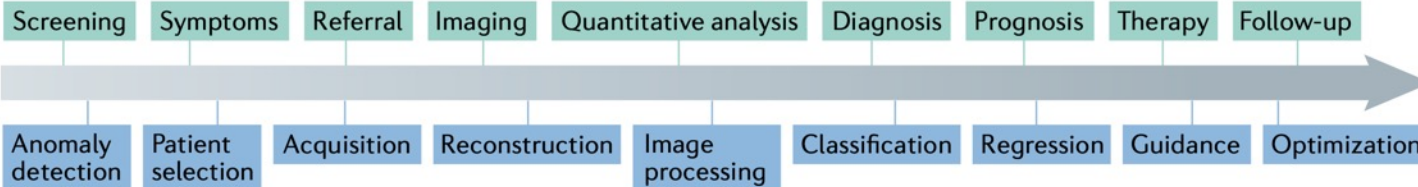
Applications of artificial intelligence in cardiovascular imaging

Maxime Sermesant , Hervé Delingette, Hubert Cochet, Pierre Jaïs & Nicholas Ayache

Clinical workflows



AI-supported decision-making

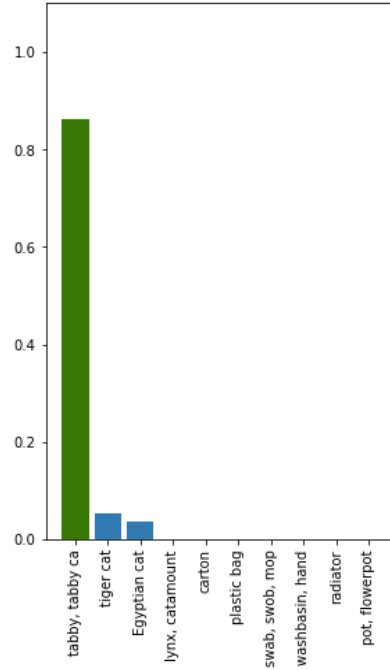


AI-based algorithms

Deep Learning Frightening Flaw: Robustness...

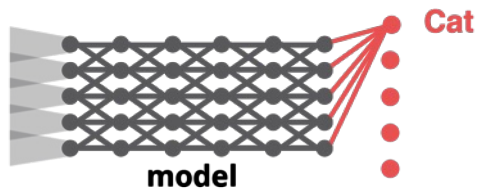


50 100 150 200 250

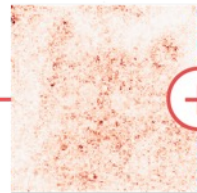
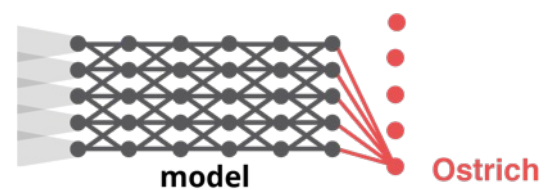


Adversarial Attack

Original image

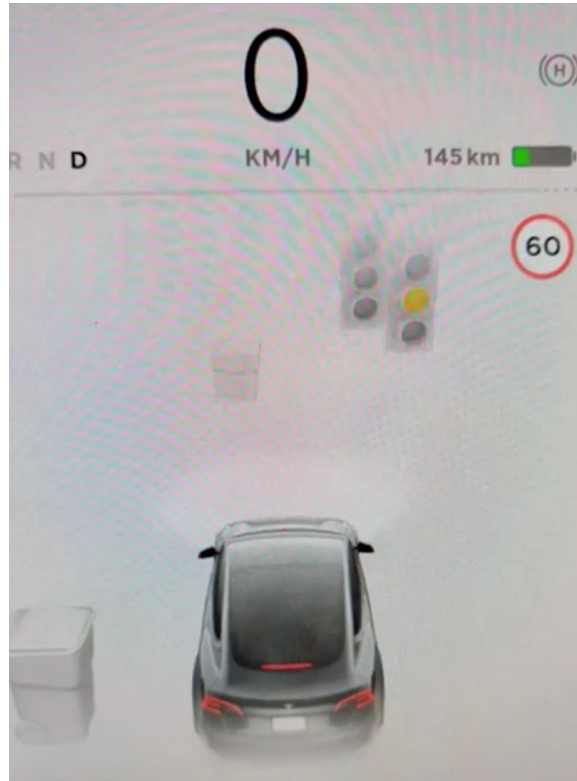


Adversarial image



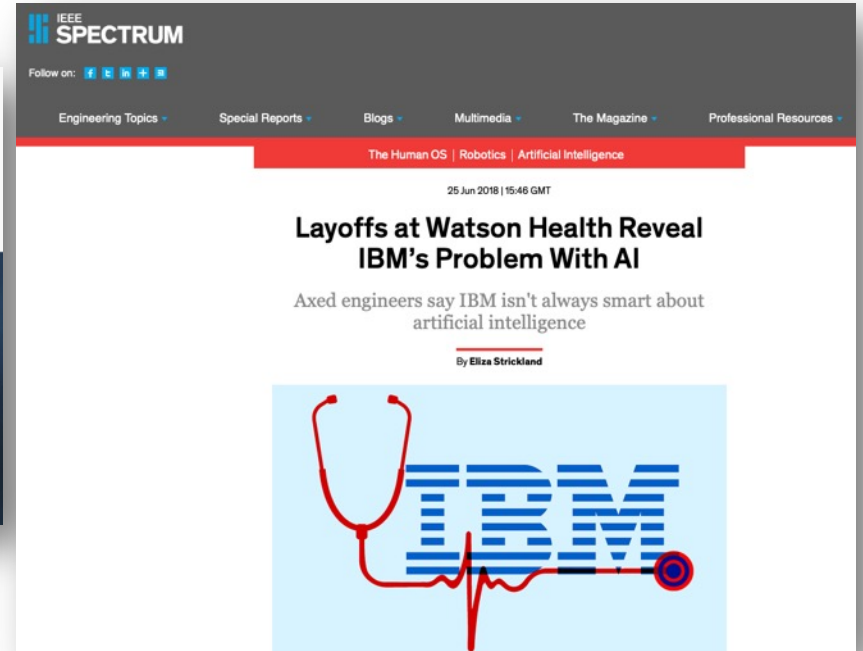
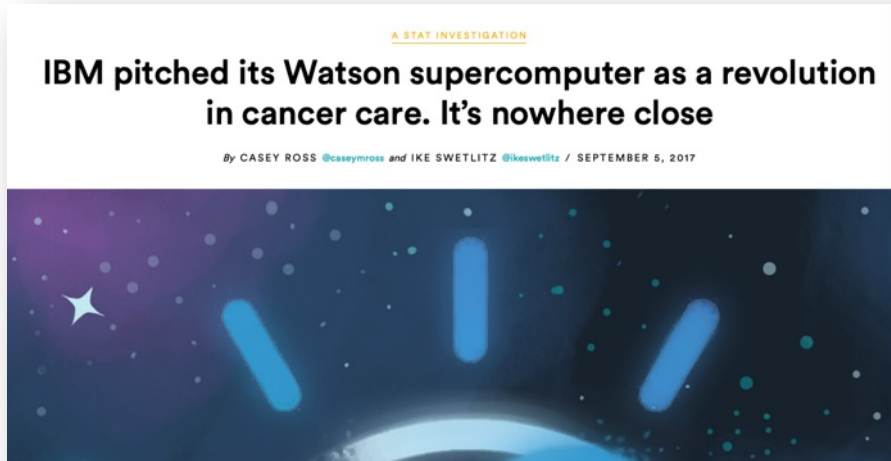
(small) adversarial perturbation
created by **attack**

Even in critical products (Tesla Car AutoPilot)



But also...

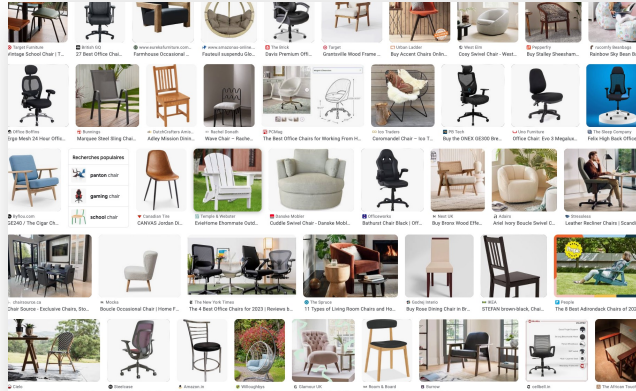
→ failures when trying to replace clinicians...



Deep Learning Limitations

Only correlations:

- No reasoning
- No abstraction
- No causality
- No emotions



« We are still very far from a rat brain » Yann LeCun

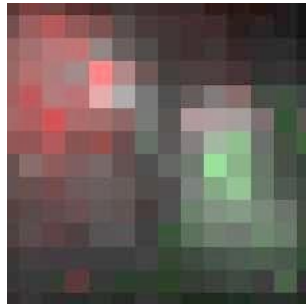
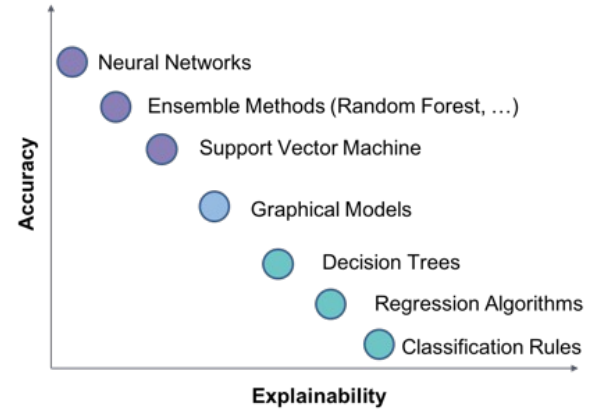
Deep Learning Limitations

Black box:

No explainability

No interpretation

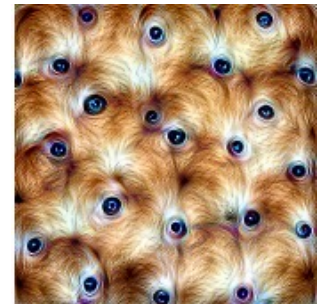
→ try to visualise what is happening



Attention map



Training set



Activating features

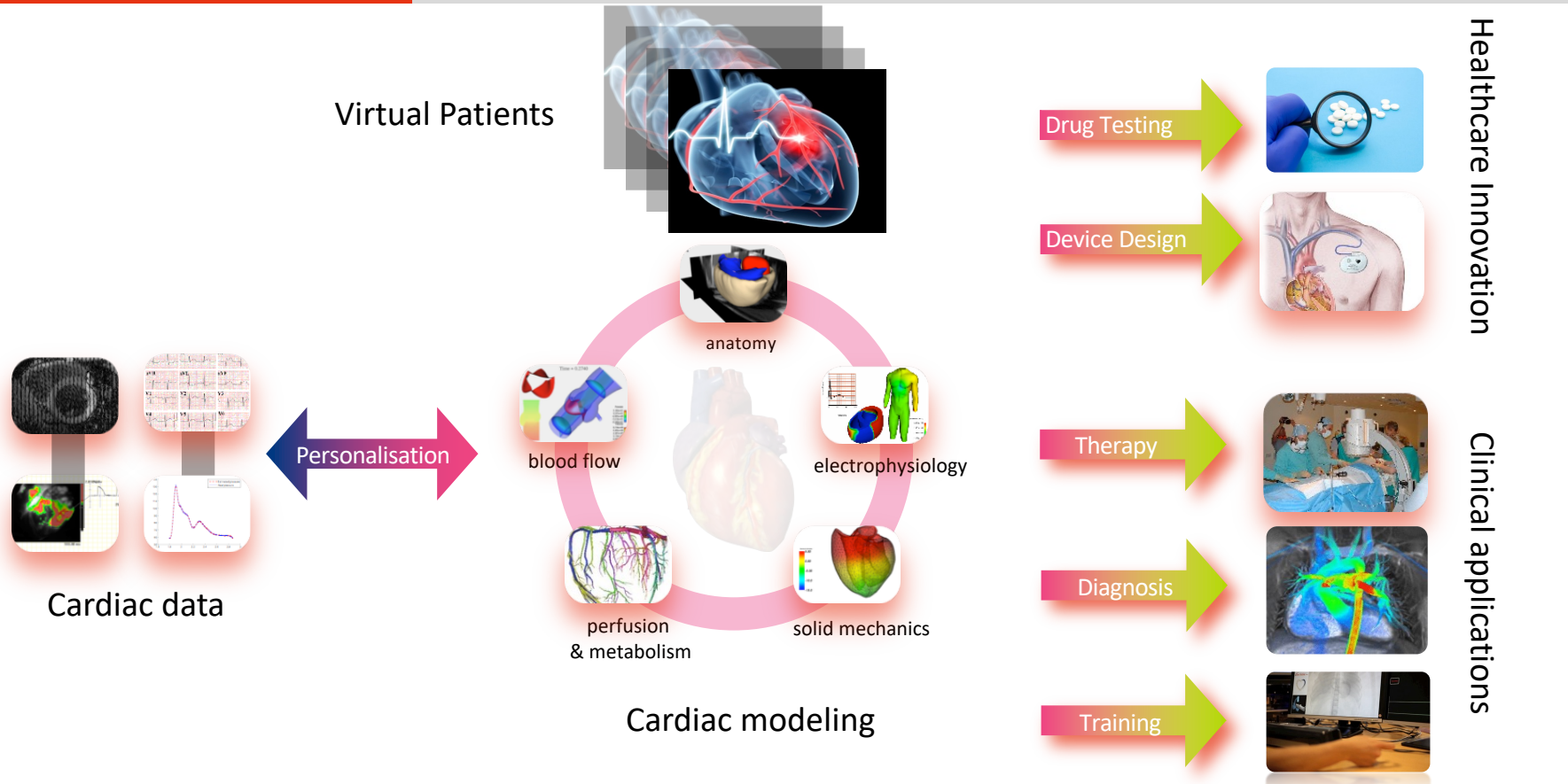
02

Comment faire apprendre la physiologie cardiaque à l'IA ?

Les mathématiques sont un langage qui permet de formaliser les connaissances de la physique, biologie, physiologie, anatomie...

Un modèle mathématique est une **traduction** des observations pour lui appliquer les outils mathématiques, puis en sens inverse, la traduction des résultats obtenus en **prédictions** dans le monde réel.

Cardiac Digital Twins

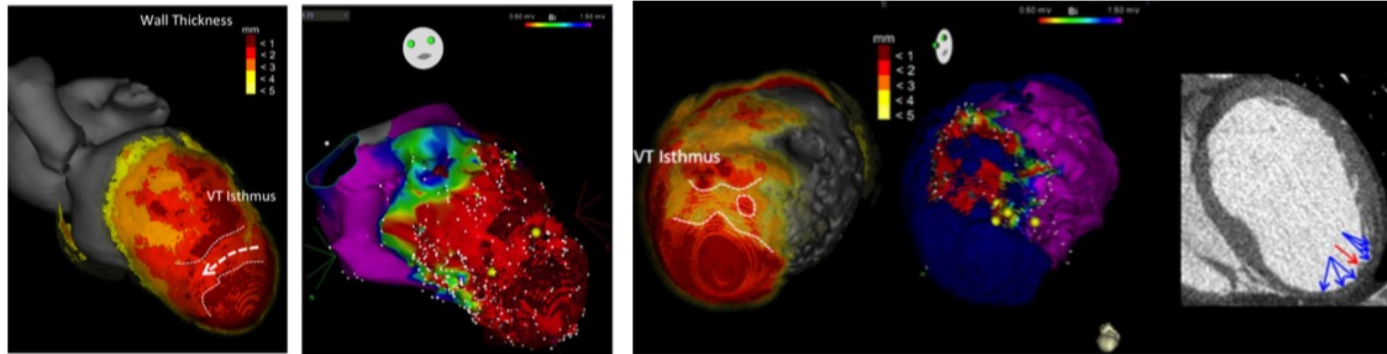


Correlation between computer tomography-derived scar topography and critical ablation sites in postinfarction ventricular tachycardia

Michael Ghannam MD¹ | Hubert Cochet MD²  | Pierre Jais MD² |
Maxime Sermesant PhD³ | Smita Patel MD¹ | Konstantinos C. Siontis MD¹  |
Fred Morady MD¹ | Frank Bogun MD¹ 

Journal of Cardiovascular Electrophysiology, 2018

70 isthmuses identified
Ablation → 73% non-inducible



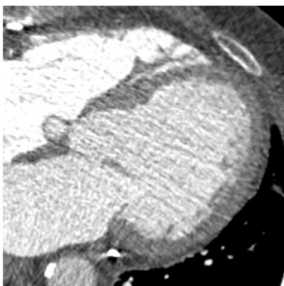
Yellow: target sites

Imaging can provide crucial information for ablation guidance

Arrhythmia Risk Prediction

I. Image Processing Pipeline

Original Input



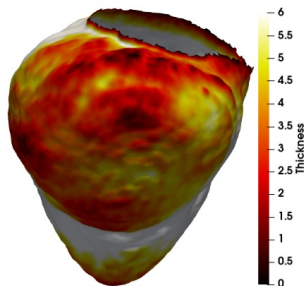
Segmentation



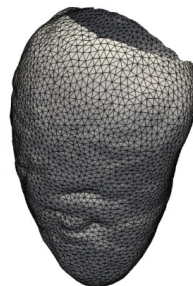
Short-Axis View



Mid-wall Mesh



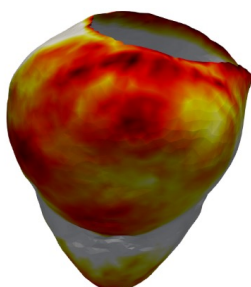
Atlas Mesh



Evaluation Results

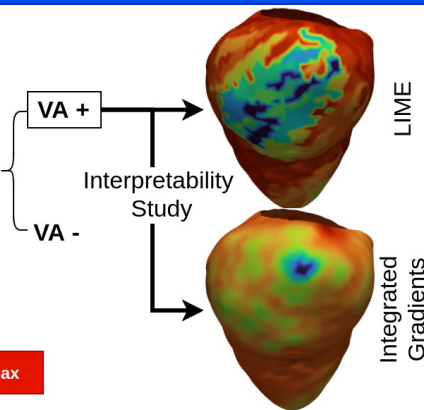
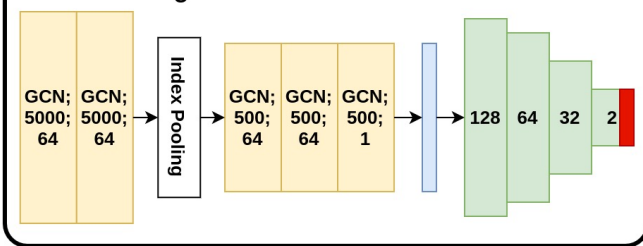
	Accuracy
GCN-Pooling $N=5000$	0.812
CVAE-Class	0.792
Scar Size > 65.49 cm ²	0.725
Scar Age > 132 months	0.698
LVEF < 43 %	0.671

II. VA Prediction & Interpretability Study



Thickness Input

GCN-Pooling Model



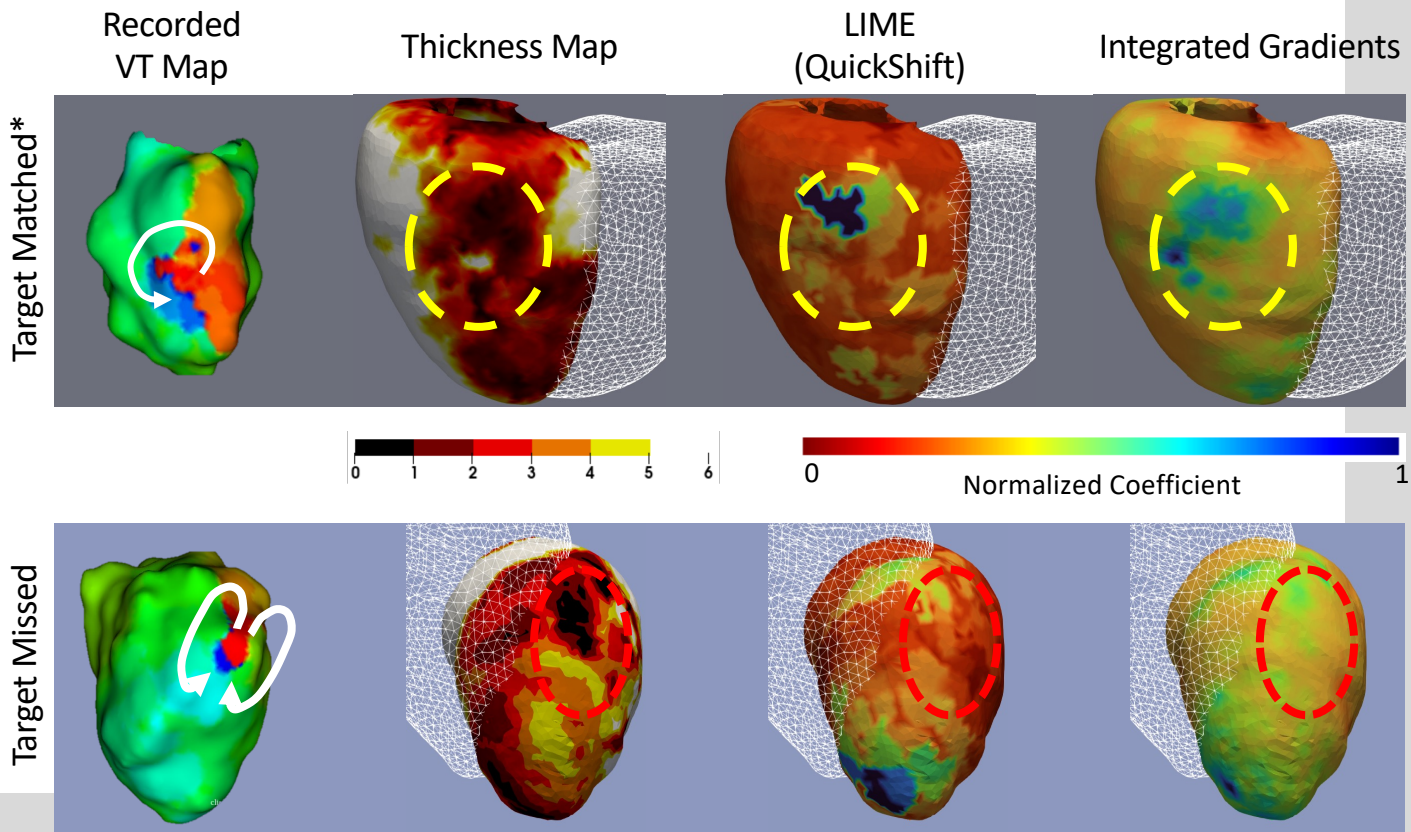
Layers legend:

GCN Layer; Nb of nodes; Nb of filters	(Dense + ReLU); Nb of units	Flatten layer	Softmax
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Evaluation of Substrate detection on Real EP Data

GCN-Pooling model achieved 90% VA prediction accuracy and correctly located 7 out of 9 circuits (78%).

	VA+ Prediction	Target Matched*
001	✓	✓
002	✓	✓
003	✓	✓
004	✓	✗
005	✗	✗
006	✓	✗
007	✓	✓
008	✓	✓
009	✓	✓
010	✓	✓

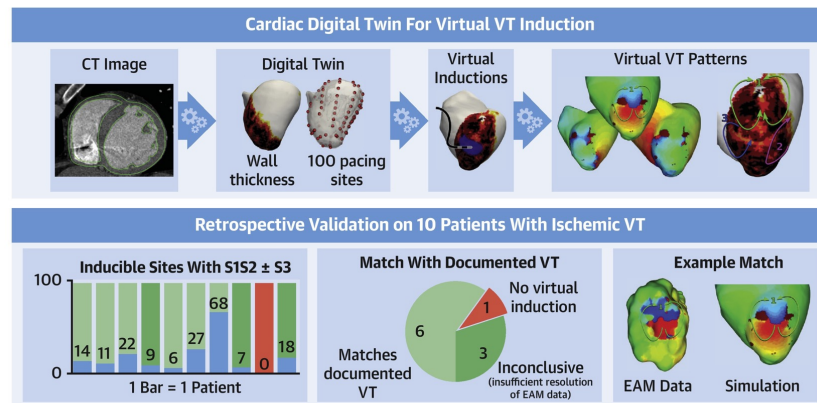


ORIGINAL RESEARCH PAPER

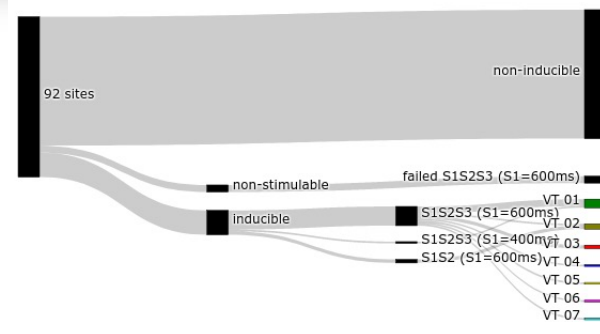
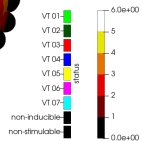
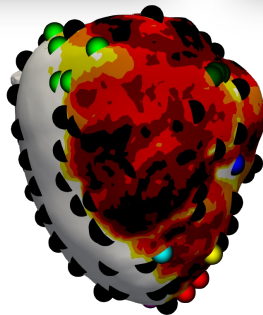
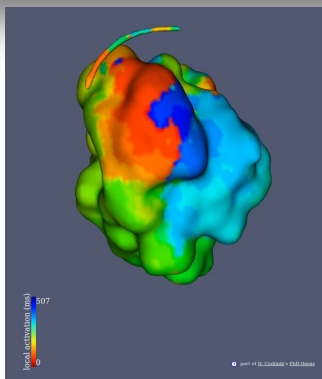
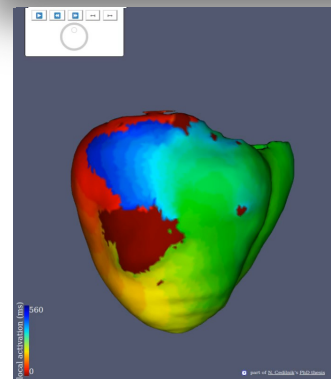
Efficient Patient-Specific Simulations of Ventricular Tachycardia Based on Computed Tomography-Defined Wall Thickness Heterogeneity

Nicolas Cedilnik, PhD,^{a,b} Mihaela Pop, PhD,^a Josselin Duchateau, MD, PhD,^{b,c} Frédéric Sacher, MD, PhD,^{b,c} Pierre Jaïs, MD, PhD,^{b,c} Hubert Cochet, MD, PhD,^{b,d} Maxime Sermesant, PhD^{a,b}

CENTRAL ILLUSTRATION: Flowchart of 3-Dimensional Computed Tomography-based Biventricular Model Construction



Cedilnik N, et al. J Am Coll Cardiol EP. 2023;■(■):■-■.



Simulated – Reentry Mechanism

We can use models to explain AI Predictions:

Test Data	31
VT Inducible	27
Target Matched*	26

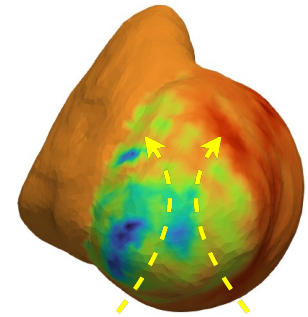
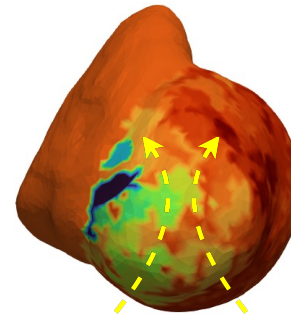
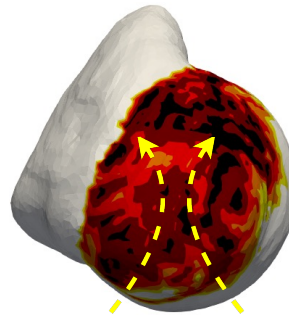
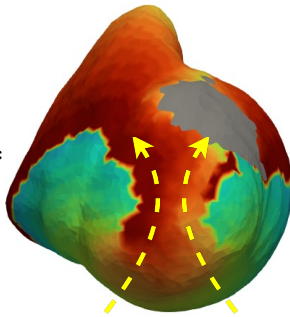
Induced Reentry Channel

Thickness Map

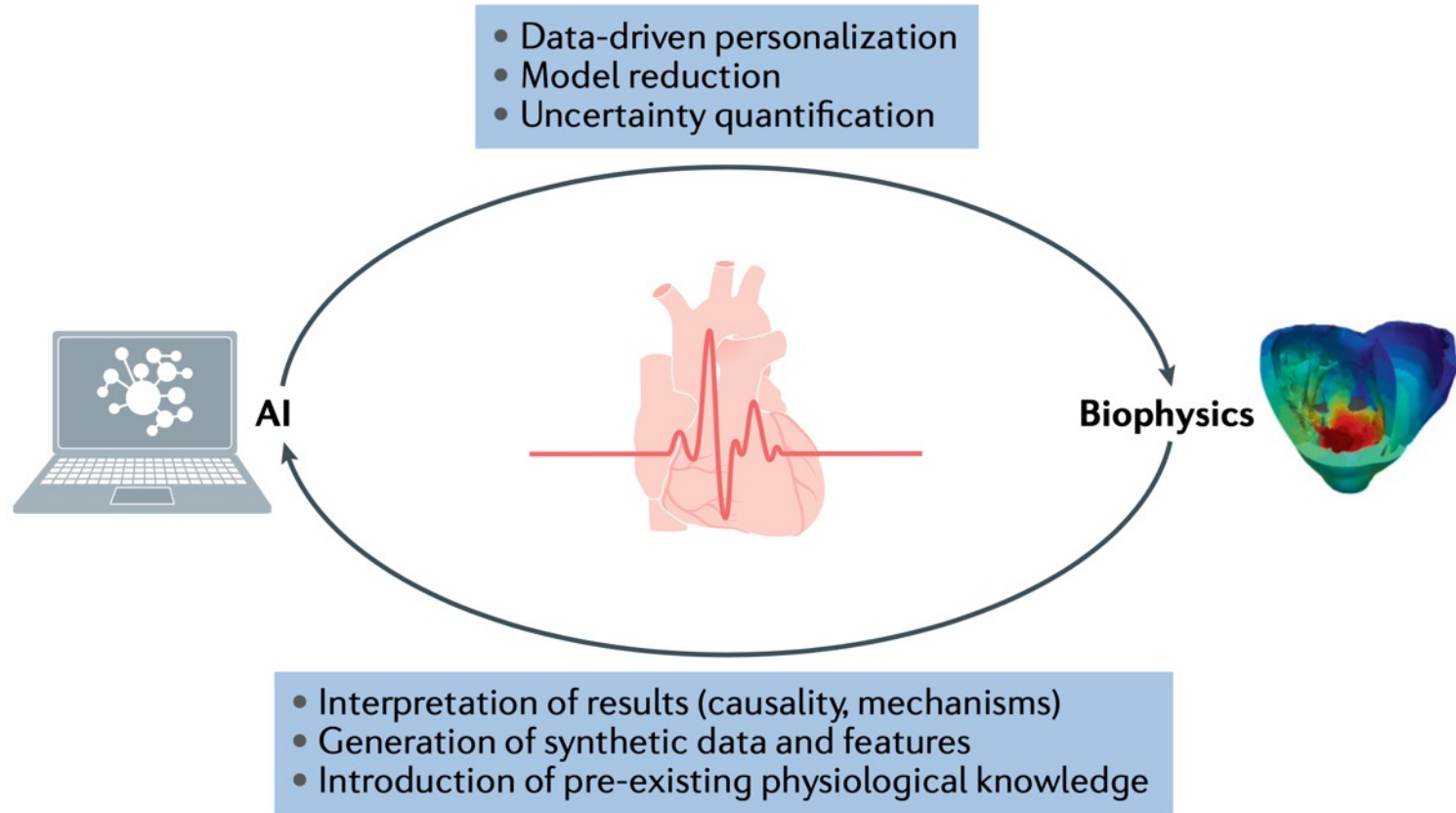
LIME (QuickShift)

Integrated Gradients

Target Matched*



Models & Artificial Intelligence



M. Sermesant, H. Delingette, H. Cochet, P. Jaïs, N. Ayache. Applications of artificial intelligence in cardiovascular imaging, *Nature Reviews Cardiology* (2021)

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