AI for CMR Postprocessing

Automatic quantification of cardiac indices: where are we ?

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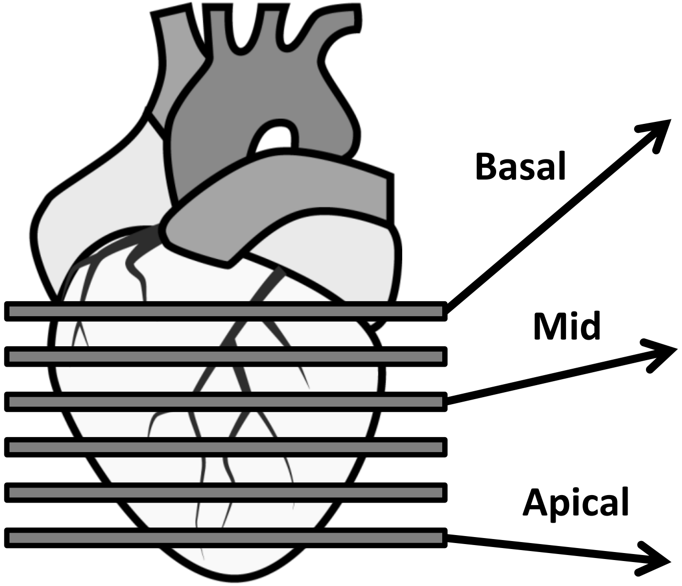
SCMR
Society for Cardiovascular Magnetic Resonance

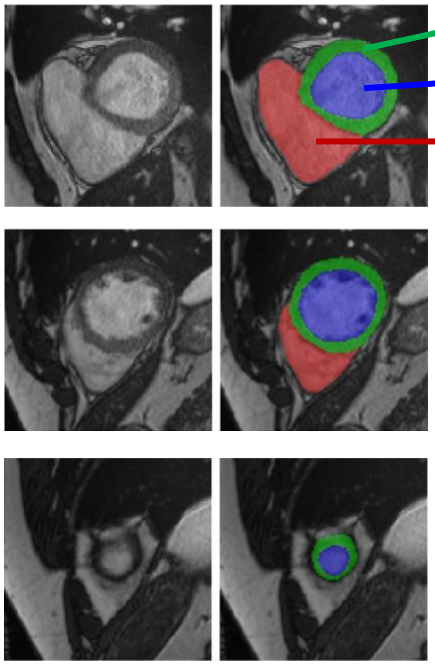
EACVI
European Association of Cardiovascular Imaging
European Society of Cardiology

No conflict to declare

Quantification of clinical indices

- Segmentation of cardiac structures





- Clinical indices
  - → LV volumes
  - → RV volumes
  - → MYO masse
  - → LV/RV ejection fraction

Segmentation of cardiac structures

- Huge literature
- UK biobank dataset
- Open access datasets with online evaluation platform
- Capacity to compare and still improve methods
- Information in the inter / intra observer variability

CMRI datasets

Name	Year	Nb Subjects		Ground truth				Genericity		Online evaluation
		train	test	LV	RV	Myo	Pathology	× Centre	× Vendor	
Sunnybrook	2009	45	—	✔	✘	✔	✔	✘	✘	✘
STACOM	2011	100	100	✔	✘	✔	✘	✘	✘	✘
MICCAI RV	2012	16	32	✘	✔	✘	✘	✘	✘	✘
Kaggle	2015	500	200	✘	✘	✘	✘	✘	✘	✘
ACDC	2017	100	50	✔	✔	✔	✔	✘	✘	✔
M&Ms	2020	150	200	✔	✔	✔	✔	✔	✔	✘

Segmentation of cardiac structures

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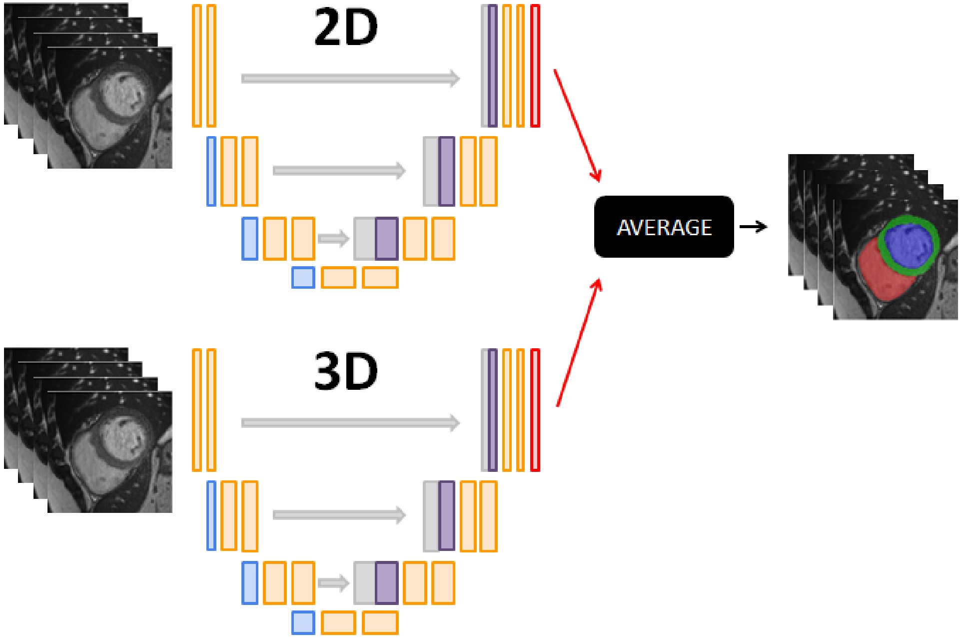
[Bernard, IEEE TMI, 2018]

U-Net based on ensemble theory



- Combination of U-Net models improve accuracy
- Different optimization schemes per model
  - ➔ 3D U-Net: cross-entropy
  - ➔ 2D U-Net: multiclass Dice

U-Net based on ensemble theory

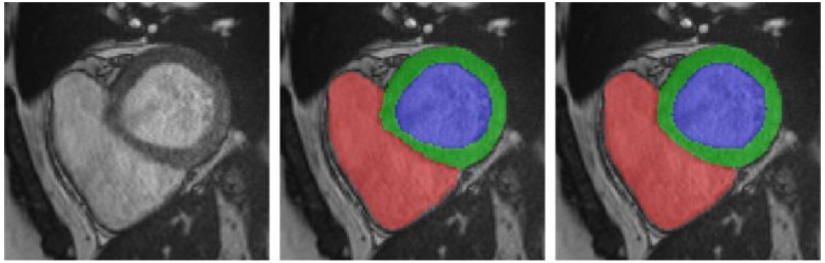
Anatomical metrics (max. distances)

Methods	LV Hausdorff dist. (mm)	RV Hausdorff dist. (mm)	Myocardium Hausdorff dist. (mm)
Inter-observer	7,1	13,2	7,4
Intra-observer	4,7	8,4	5,6
AI method	7,2	11,1	8,7

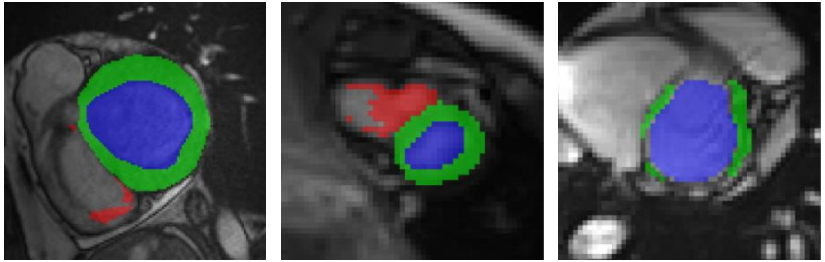
Clinical metrics

Methods	LV EF Correlation	RV EF Correlation	Myo. Mass Correlation
AI method	0,991	0,901	0,989

High segmentation quality



With few incoherence



Segmentation of cardiac structures

CMRI datasets										
Name	Year	Nb Subjects		Ground truth				Genericity		Online evaluation
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M&Ms	2020	150	200	✔	✔	✔	✔	✔	✔	✘

- M&Ms: Multi-centre / vendor / disease open access study
  - ▶ 4 different scanners (Siemens, Philips, GE and Canon)
  - ▶ 9 different pathologies
  - ▶ 6 different hospitals in Spain, Germany and Canada

Evaluation of the generalization capacity of AI models

[Campello, IEEE TMI, 2021]

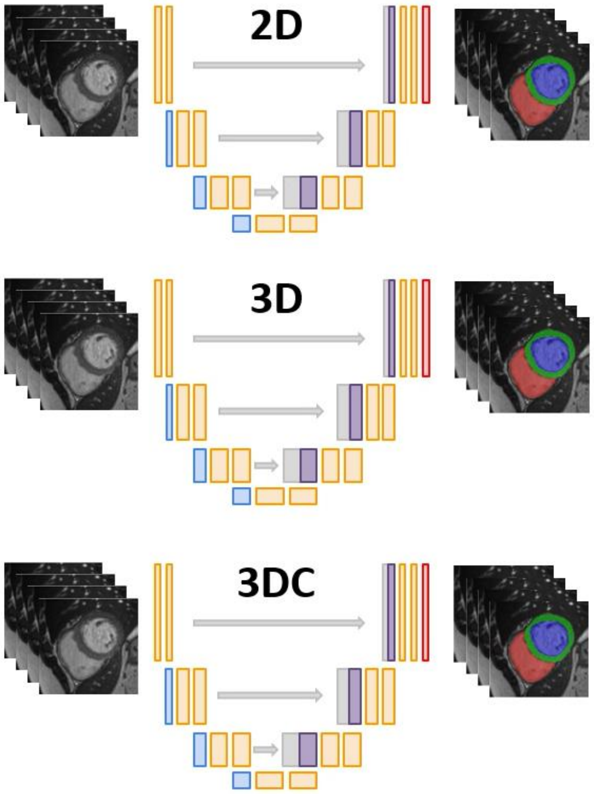
nnU-Net architecture

Training phase

Data Preprocessing

Architecture optimization

Data augmentation



Testing phase

Ensemble strategy

Data augmentation

nnU-Net architecture

Anatomical metrics

Methods	LV Hausdorff dist. (mm)	RV Hausdorff dist. (mm)	Myocardium Hausdorff dist. (mm)
Inter-observer	7,1	13,2	7,4
Intra-observer	4,7	8,4	5,6
AI method (ACDC)	7,2	11,1	8,7
AI method (M&Ms)	9,1	12,2	11,7

- **Data augmentation strategy is the current best solution for generalization**

→ **Spatial transformation**

→ **Intensity transformation**

And so, where are we ?

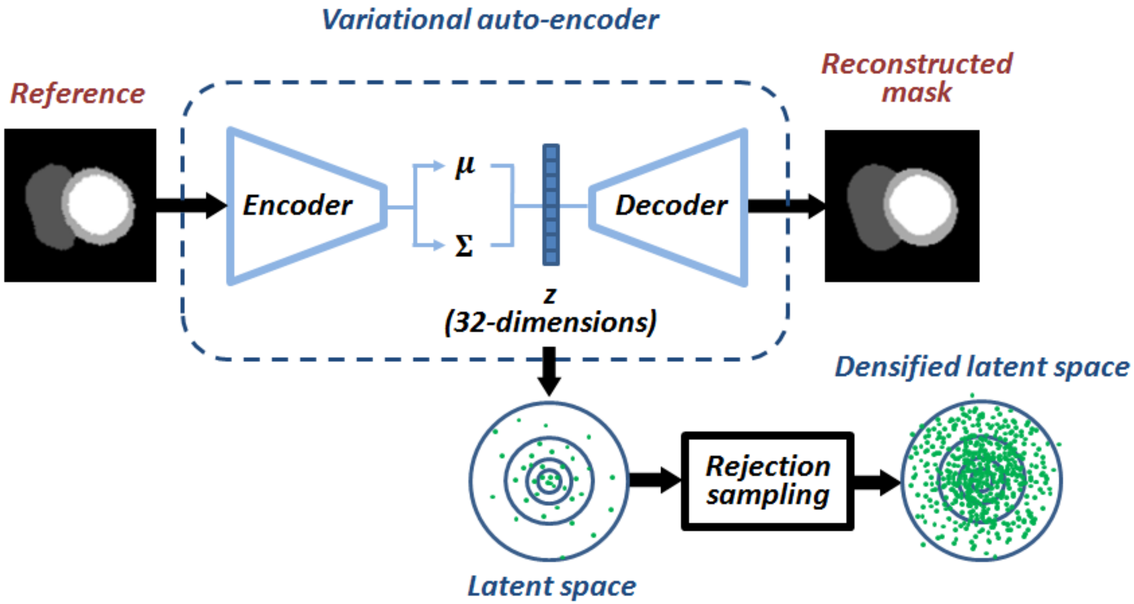
- High correlation with radiologists for the automatic measurement of clinical metrics from mono-centre study

But, needs for

- Reinforcement of the generalization capacity
- Breaking the black-box syndrome
  - Segmentation with anatomical guarantees
  - Segmentation with temporal coherence guarantees

How to obtain segmentation with anatomical guarantees ?

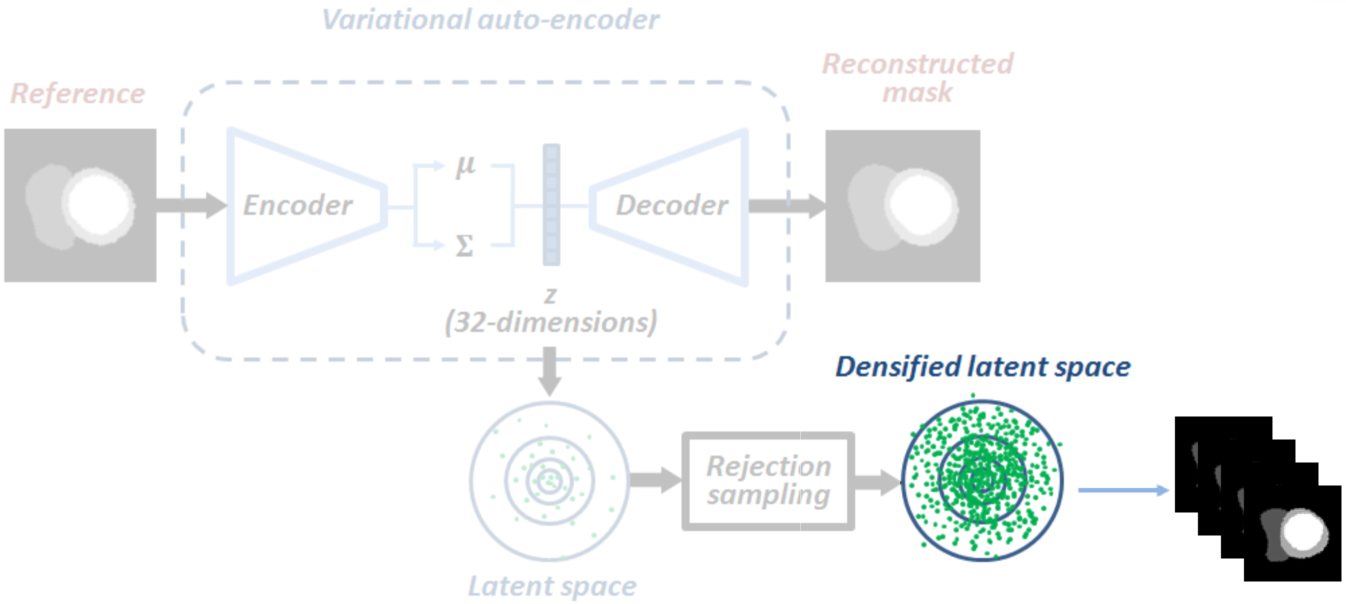
Anatomical coherence



Efficient encoding of anatomical shapes in a latent space

[Painchaud, IEEE TMI, 2020]

Anatomical coherence



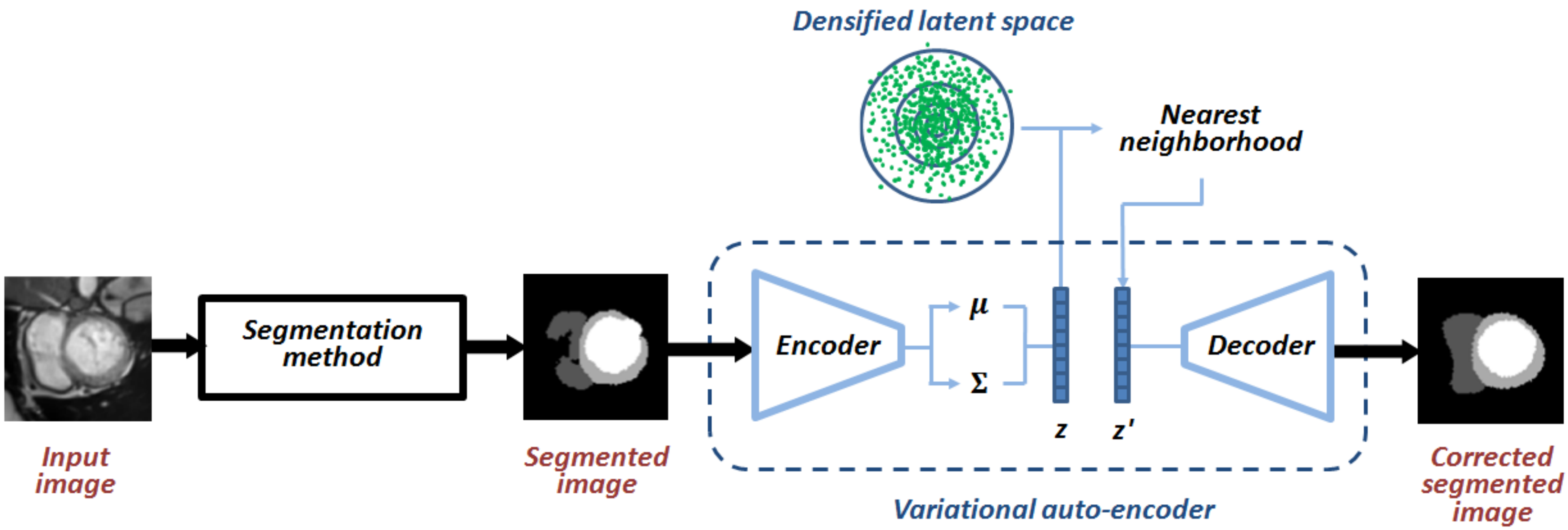
16 anatomical metrics

[Painchaud, IEEE TMI, 2020]

Anatomical coherence

Correction of segmentation to guarantee the plausibility of anatomical shapes

Almost same accuracy than the original methods but with correct anatomical shapes



[Painchaud, IEEE TMI, 2020]

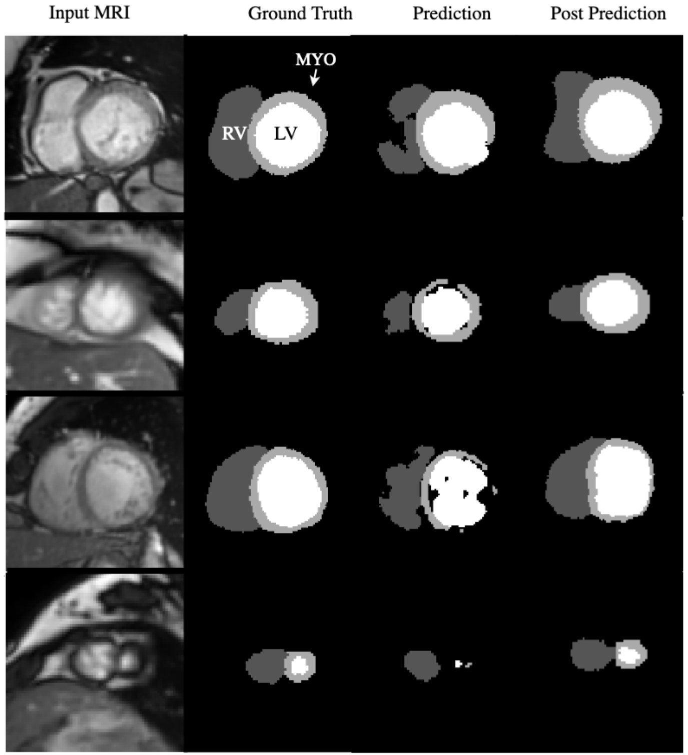
U-Net with anatomical guarantees

Anatomical metrics from ACDC

Methods	LV/RV/Myo. Hausdorff dist. (mm)	# Outliers (%)
Inter-observer	9,2	-
Intra-observer	6,2	-
AI method	9,1	12
With anat. guarantees	9.2	0

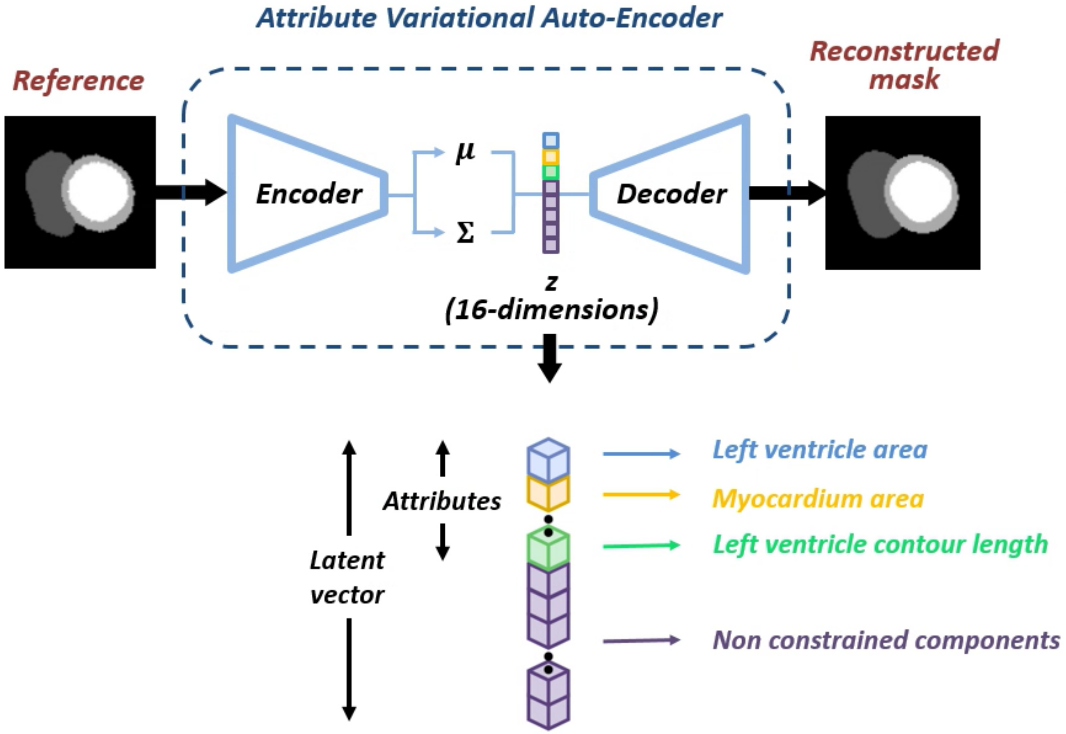
Clinical metrics from ACDC

Methods	LV EF Mean Error (%)	RV EF Mean Error (%)
AI method	2.2	4.8
With anat. guarantees	2.2	4.8



How to obtain segmentation with enforced temporal coherence ?

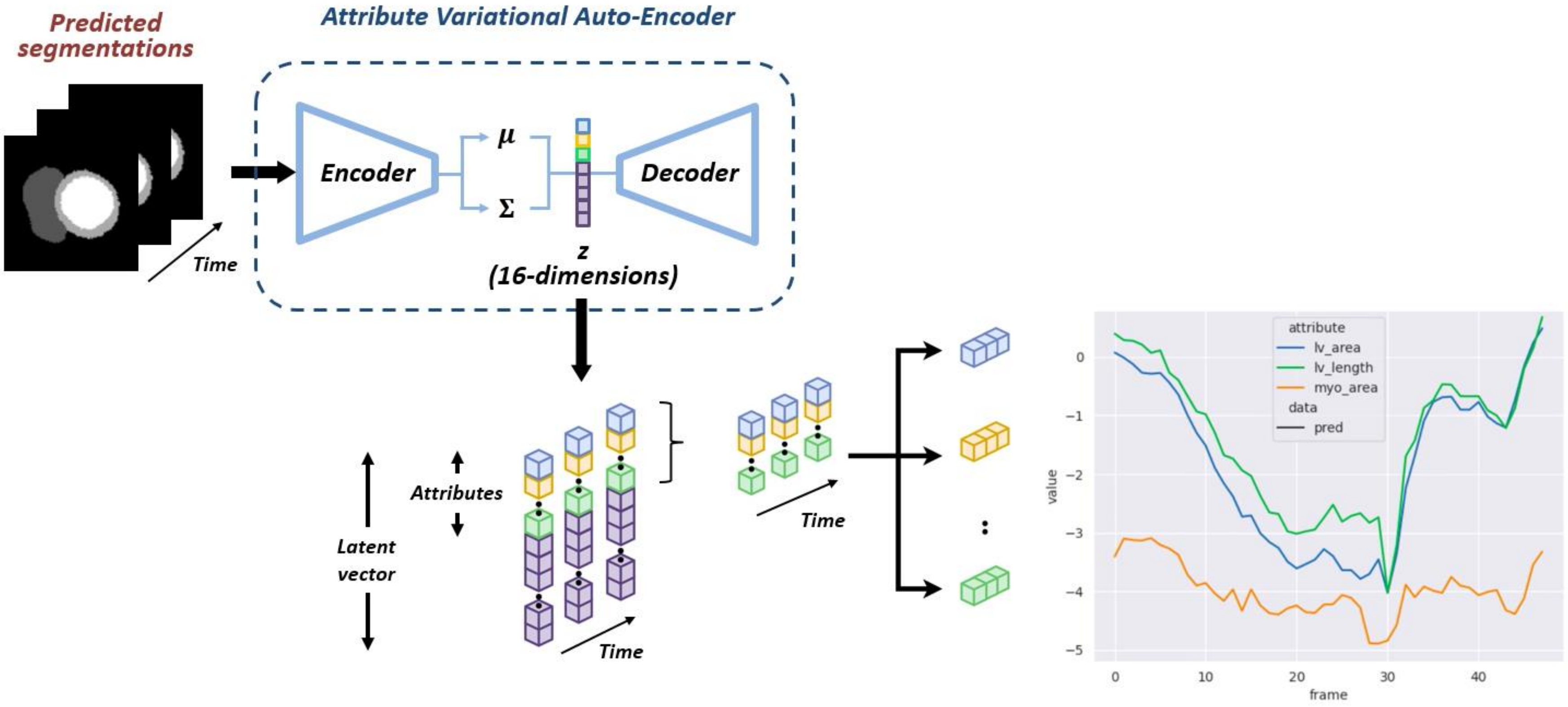
Temporal consistency



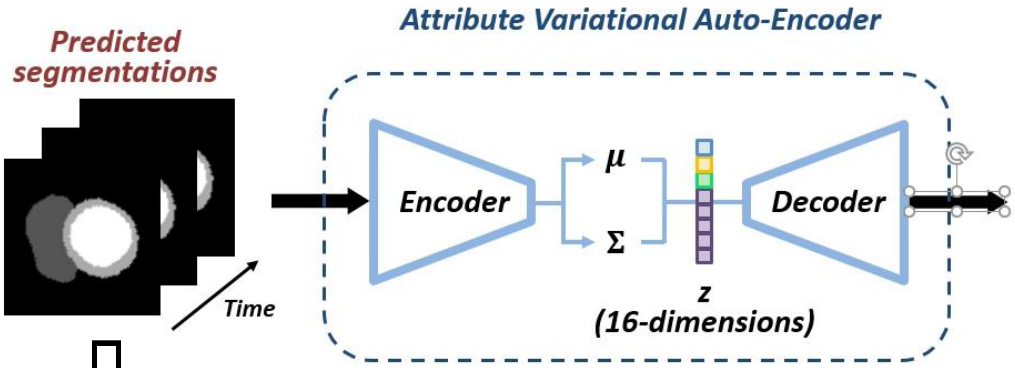
Efficient encoding of anatomical shapes with controlled attributes

[Painchaud, IEEE TMI, 2022]

Temporal consistency



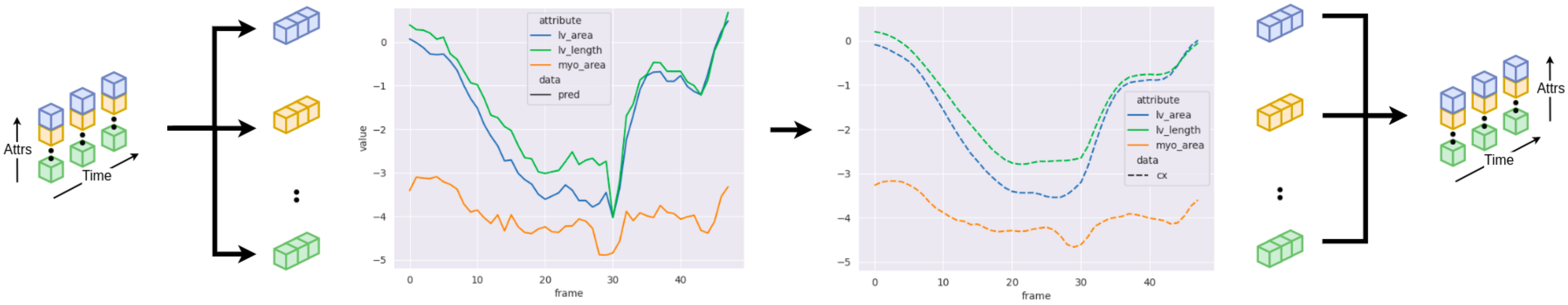
[Painchaud, IEEE TMI, 2022]



Build attributes' sequence from encoding

Smooth attributes from the latent space

Reconstruct encoding from smoothed attributes



[Painchaud, IEEE TMI, 2022]

Temporal consistency

Thank you for your attention

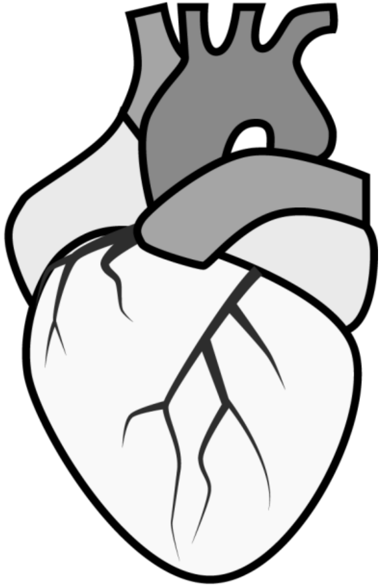
Appendices

General overview of the application of AI in CMR

Intensive research topics

- Among the hottest topics

Improvement of the acquisition process



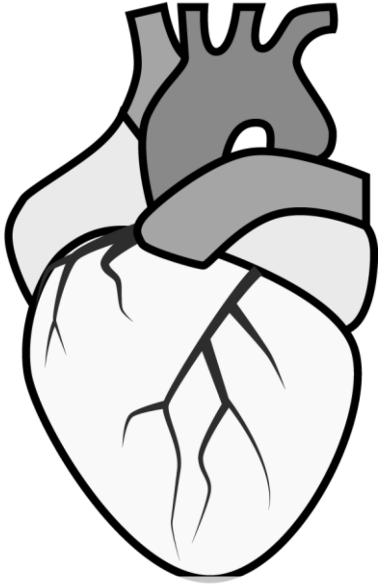
Automatic quantification of clinical indices

Population representation learning

Intensive research topics

- **Among the hottest topics**

Improvement of the acquisition process



Automatic quantification of clinical indices

Population representation learning