Cardiac Segmentation With Strong Anatomical Guarantees

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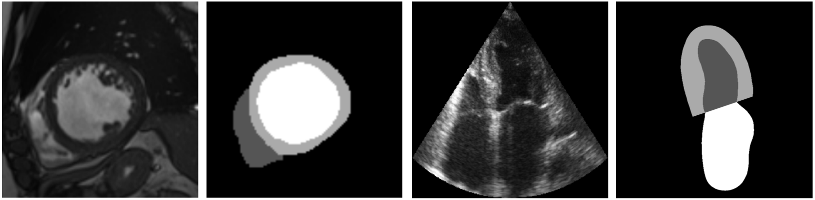
Cardiac Imaging

2 modalities & 3 acquisition protocols
$\rightarrow$ diverse images and cardiac shapes



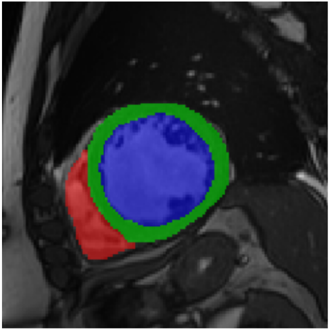
(a) Short-axis MRI (b) Long-axis echocardiography (US)

Examples of images from different modalities, with their annotations.

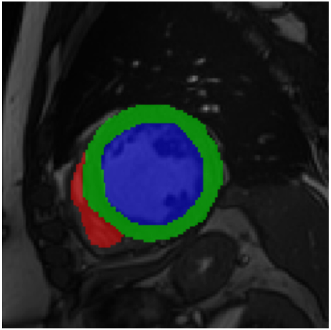
Cardiac Imaging: Cardiac Function

Objective

Determine the images' underlying **cardiac anatomy** to analyze the **cardiac function**.



(a) Heart at end diastole



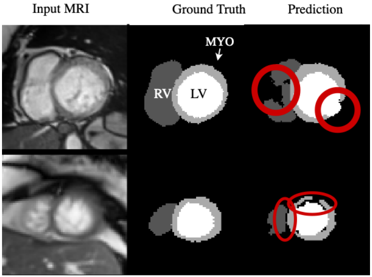
(b) Heart at end systole

Automatic Cardiac Segmentation

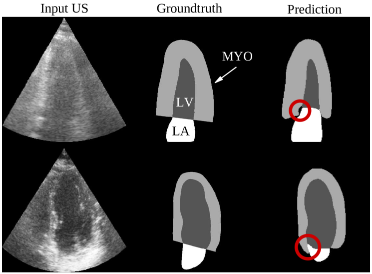
Segmentation using deep neural networks:

☑ Inter-observer variability
(Dice coeff., Hausdorff dist.)

✗ Anatomical guarantees



(a) MRI



(b) US

[**Painchaud** et al., *IEEE TMI*, 2020]

Overview

Post-processing of **anatomically invalid** images

- Before processing the images, we:
  1. define anatomical criteria;
  2. learn a model of cardiac shapes.

- While processing images, we:
  1. segment the images;
  2. evaluate the anatomy of the segmented shapes;
  3. correct invalid segmentations.

Anatomical Criteria

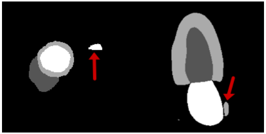
12 to 16 **handcrafted** metrics, i.e. implemented by code

(a) Intra-region holes

(b) Inter-region holes

(c) Concavity

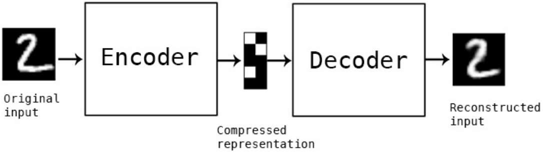
(d) Connectivity between LV and background

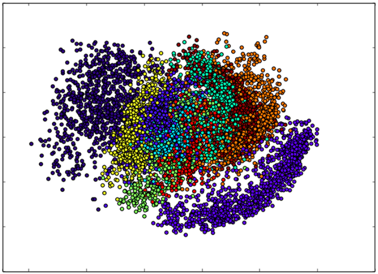


(e) Disconnectivity

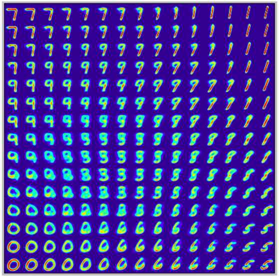
[**Painchaud** et al., *IEEE TMI*, 2020]

Autoencoders





(a) 2D encoding of digits 0-9

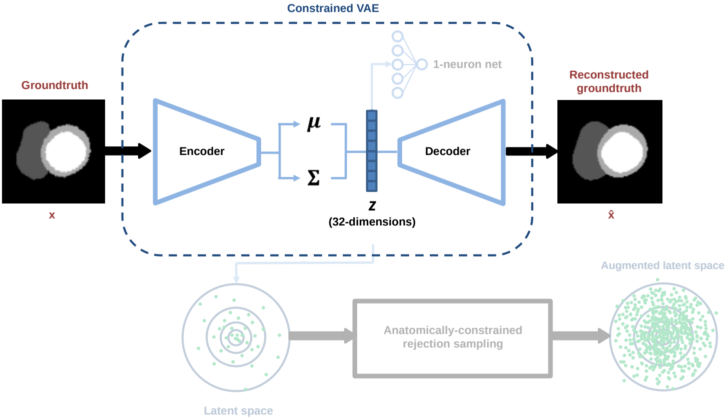


(b) Decoded 2D samples

Source: `https://blog.keras.io/building-autoencoders-in-keras.html`

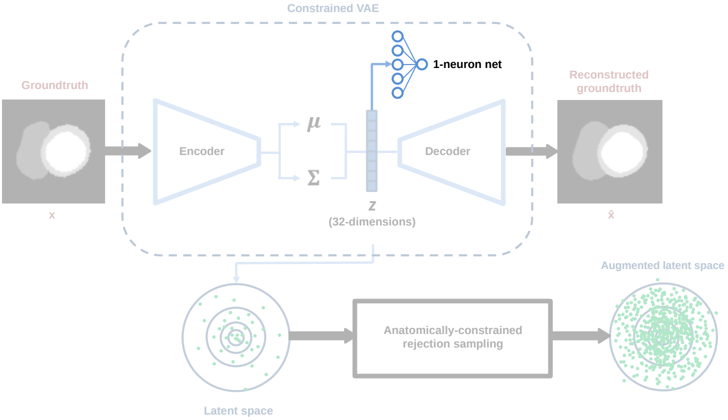
Cardiac Shape Modeling

Variational autoencoder + **topological contraint**



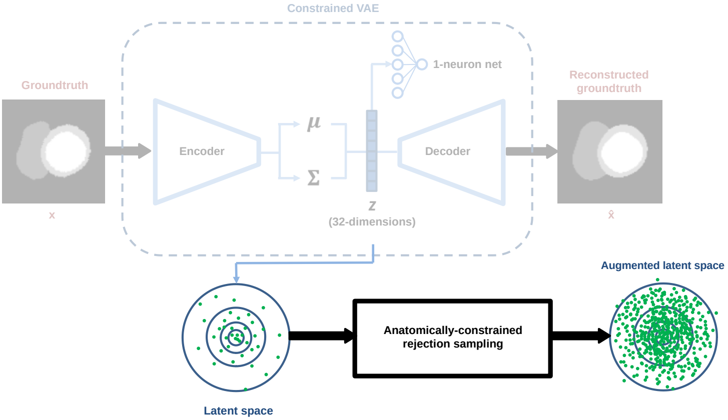
Cardiac Shape Modeling

Variational autoencoder + **topological constraint**



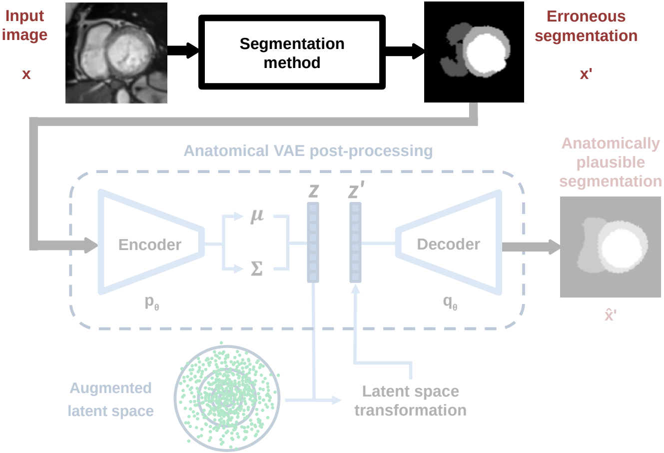
Data Augmentation through Sampling

Sample the latent space posterior to increase density.



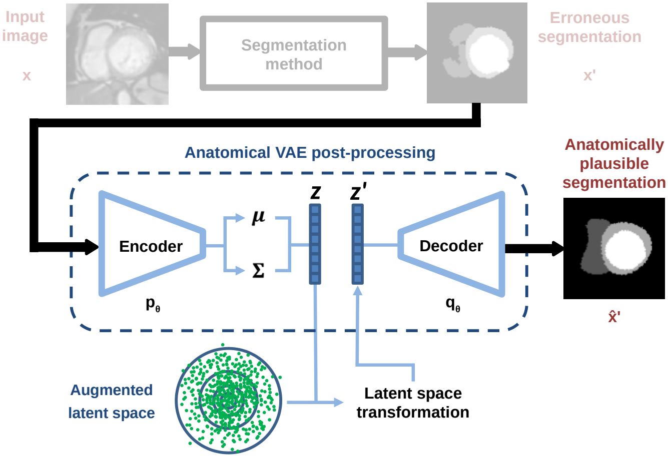
Anatomical Post-processing

Cardiac segmentation with **any chosen method**



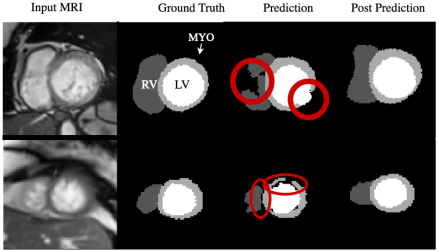
Anatomical Post-processing

Correction of invalid segmentations

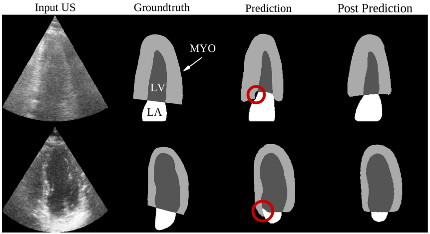


Anatomical Post-processing: Results

(a) MRI



(b) US

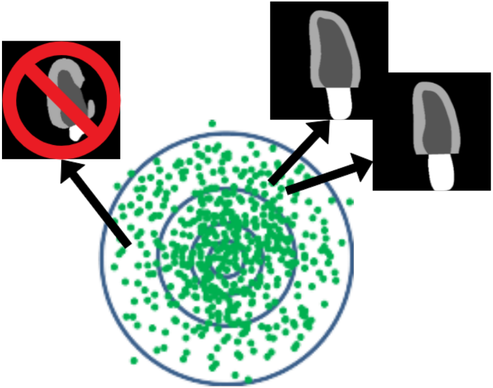


[**Painchaud** et al., *IEEE TMI*, 2020]

Deep Manifold Learning

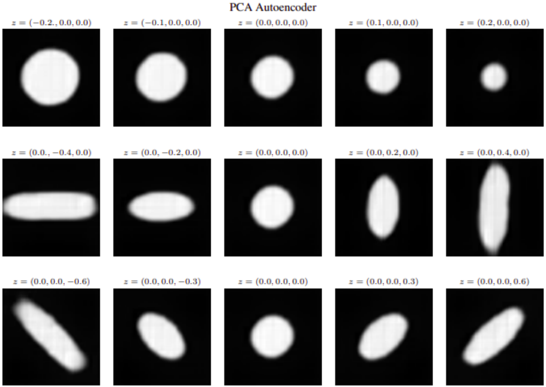
- ☑ Intra-sample anatomy
- ☐ Inter-sample similarity

Inter-image
Consistency
Interpretability



Deep Manifold Learning

Attribute Manipulation



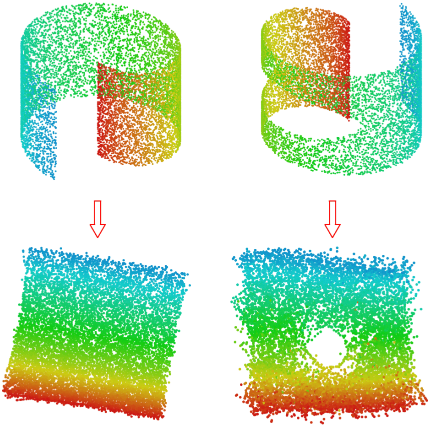
[Ladjal et al., *arXiv*, 2019]

Inter-image
Consistency
Interpretability

Thank you for listening!

Manifold Linearization

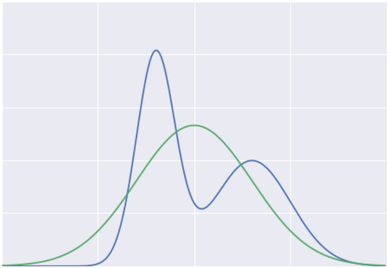
Examples of linear 2D manifolds enclosed in 3D spaces


(a) (b)

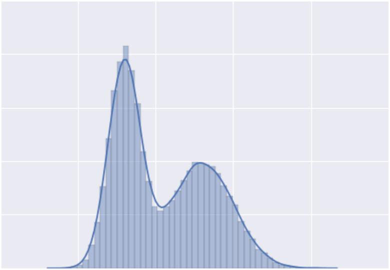
[A. Najafi et al., *IEEE T. PAMI*, 2016]

Rejection Sampling

Hard to sample target distribution (in blue).
We sample from a simpler proposed distribution (in green).



Sampling results.



Examples of rejection sampling with a 2D mixture of gaussians.