Fully automatic extraction of mitral valve annulus motion parameters on long axis CINE CMR using deep learning

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Declaration of Financial Interests or Relationships

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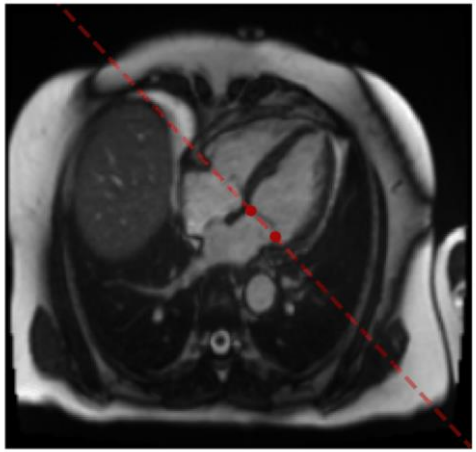
I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Problem Description

Heart Failure with preserved Ejection Fraction (HFpEF)

- Filling of left ventricle malfunctions
  - Related to Diastolic Dysfunction
  - 1.1–5.5 % general population
- Dynamic motion parameters
  - Diagnosis of dysfunction
  - CINE Cardiac Magnetic Resonance (CMR)
  - Analysis of the mitral valve annulus (MVA)
    - Atrioventicular plane displacement
    - Early diastolic velocities (e'-waves)

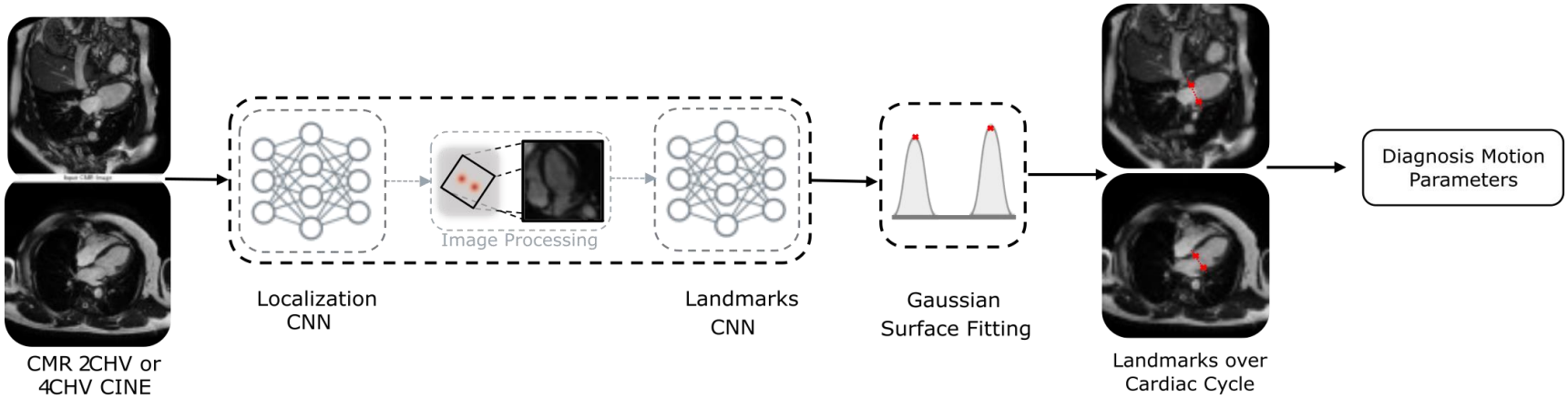


MVA plane motion

Proposed System

Fully Automated Convolutional Neural Network (CNN) Algorithm

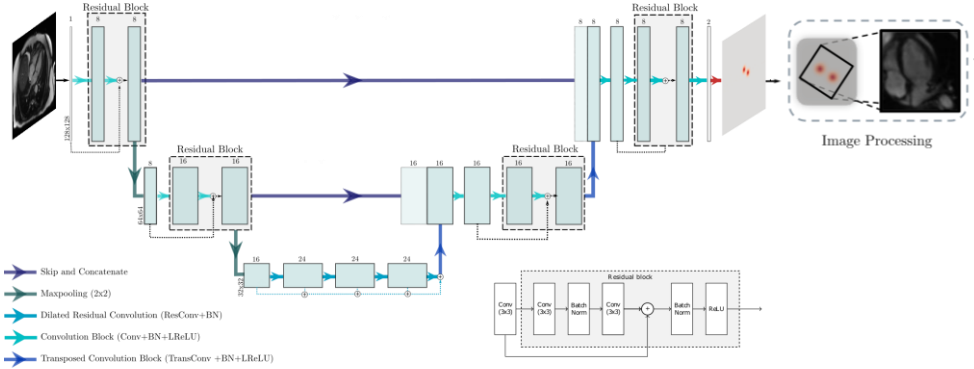
- CINE CMR series dataset
  - 2-chamber (2CHV) and/or 4-chamber (4CHV)
- Tracks MVA insertion points over complete cardiac cycle
- Automatic compute diastolic parameters



Neural Networks

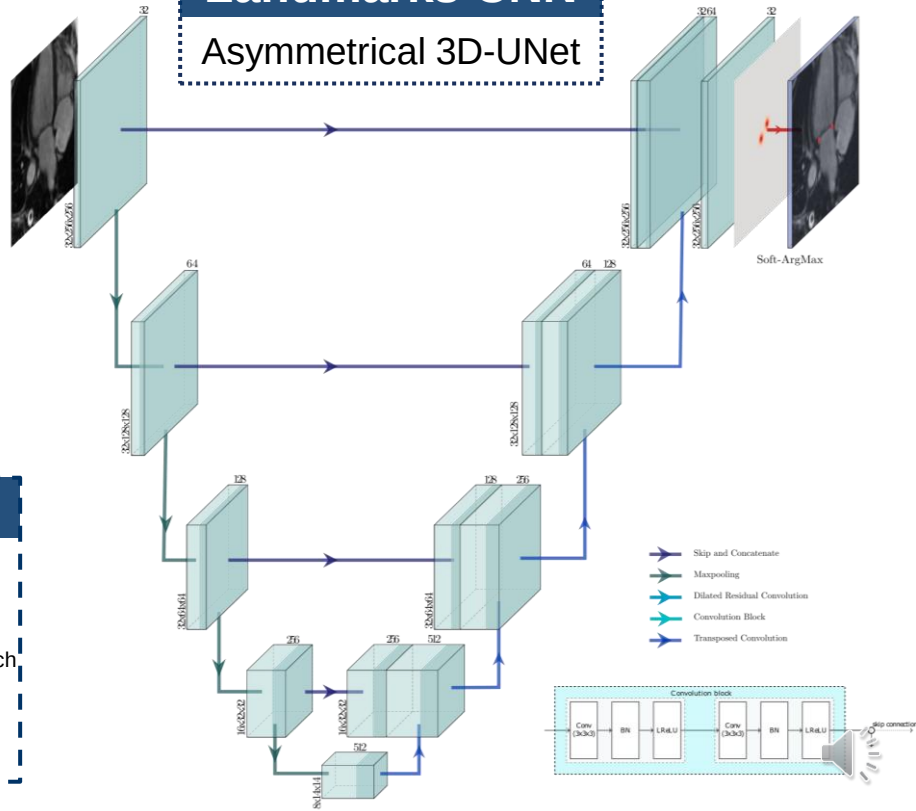
Localization CNN

Vanilla Residual 2D-UNet



Landmarks CNN

Asymmetrical 3D-UNet



Training

- Adaptive Wing Loss
- Heatmap Regression with variable target's standard deviation
  - Decreased exponentially along epochs $\sigma^{epoch} = 16 \cdot 0.95^{epoch}$
- Adam Optimizer with momentum = 0.9, learning rate = 0.0001 and weight decay regularization

Motion Parameter Extraction

MVAPD: MVA Plane Displacement

- Perpendicular distance to first cardiac phase MVA plane
- Peak Displacement (MVAPD-PD): maximum translation

MVAPV : MVA Plane Velocity

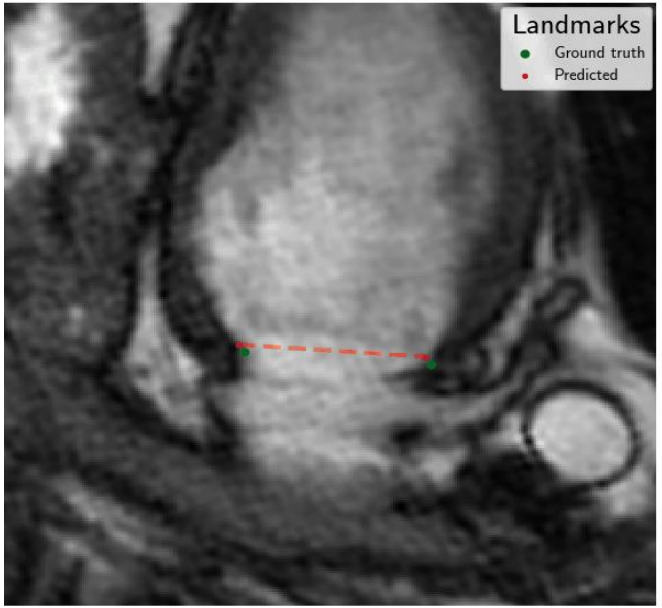
- Time-resolved discrete derivate fo MVAPD curve
- Early annular diastolic velocity (MVAPV-e'): central peak

SMVAV | LMVAV: Septal or Lateral MVA velocity

- Temporal derivative of each landmark displacement
- Annular diastolic velocities (MVAL-e'): central maximum

Mitral Valve Diameter

- Euclidean distance between both MVA through cardiac cycle
- Total displacement sum over cardiac cycle in mm (VAD)
- Maximum diameter (MAMD) and maximum difference (MADC)



Predicted landmarks and motion parameter representation

Results

Quantitative Performance

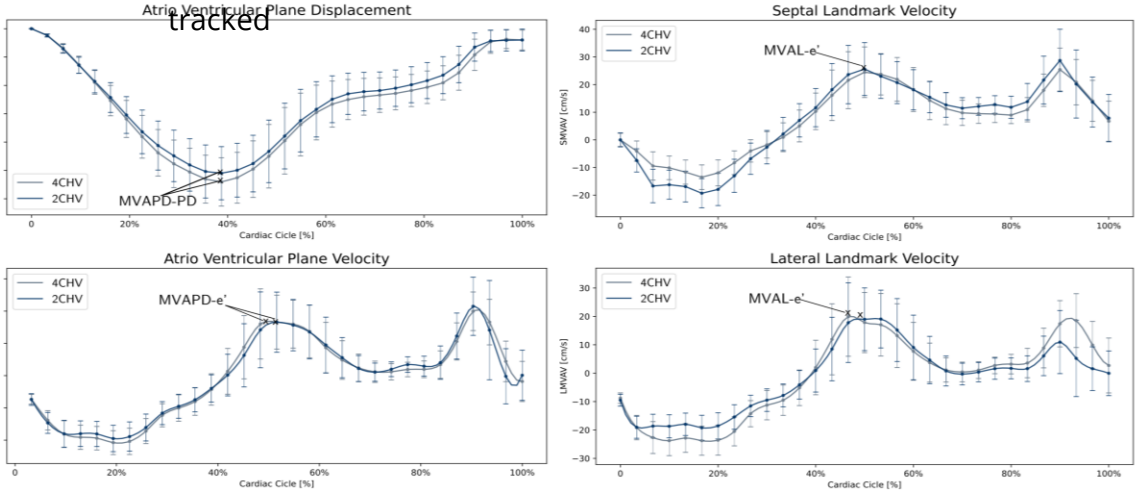
- Accuracy w.r.t test set (N=13)
- Root mean square errors
  - 2CHV: 1.75 ± 0.64 mm.
  - 4CHV: 1.74 ± 0.72 mm.
- Extracted parameters' agreement

Bland-Altman Analysis

Parameter	Value ± std	unit
MVAPD-PD	0.53 ± 2.44	mm
MVAPV-e'	0.08 ± 3.48	cm/s
VAD	15.39 ± 54.62	mm
MAVL-e'	0.12 ± 3.73	cm/s
MAMD	0.31 ± 3.66	mm
MADC	0.28 ± 3.12	mm

Qualitative Assessment on Unlabeled Data

- System performance based on outlier's detection (N=1468)
  - Localization CNN: < 0.5% to locate the ROI
  - Landmarks CNN: 16, 53% at least one time-frame not smoothly tracked



Time-resolved motion curves and extracted parameters

Conclusion

Conclusion

- ✓ Successfully track MVA landmarks
  - Mean error in the range of the data's resolution
    - Heatmap regression avoids image-coordinate domain transfer
    - Small annotated dataset size (N=83)
- ✓ Bland-Altman analysis
  - Good agreement ground truth and extracted parameters

Outlook

- Further analysis of motion parameters of categorized patient

- On-line integration at MRI scanner
- Prospective slice-tracking acquisition