

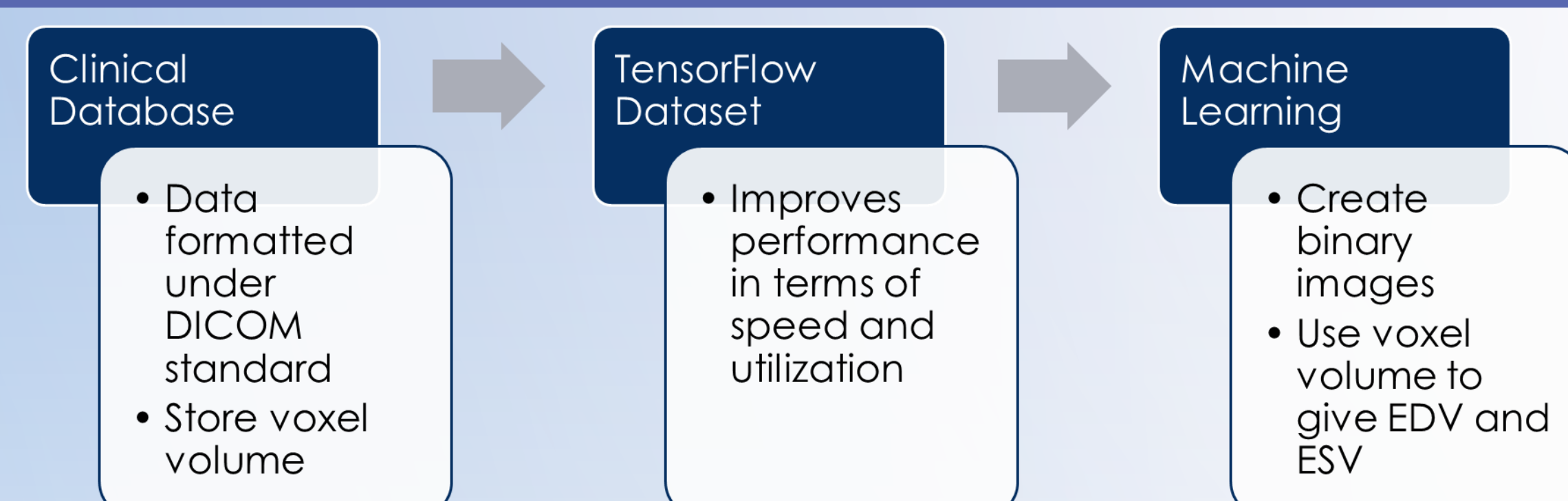
Motivation

- Left ventricle (LV) assessment in cardiac magnetic resonance (CMR) imaging is an important step in the study of cardiovascular disease.
- Manual assessment, over many patients and multiple time phases, is time consuming and prone to human error and fatigue, making automatic methods a common goal.
- Recent advances in machine learning make automation possible.

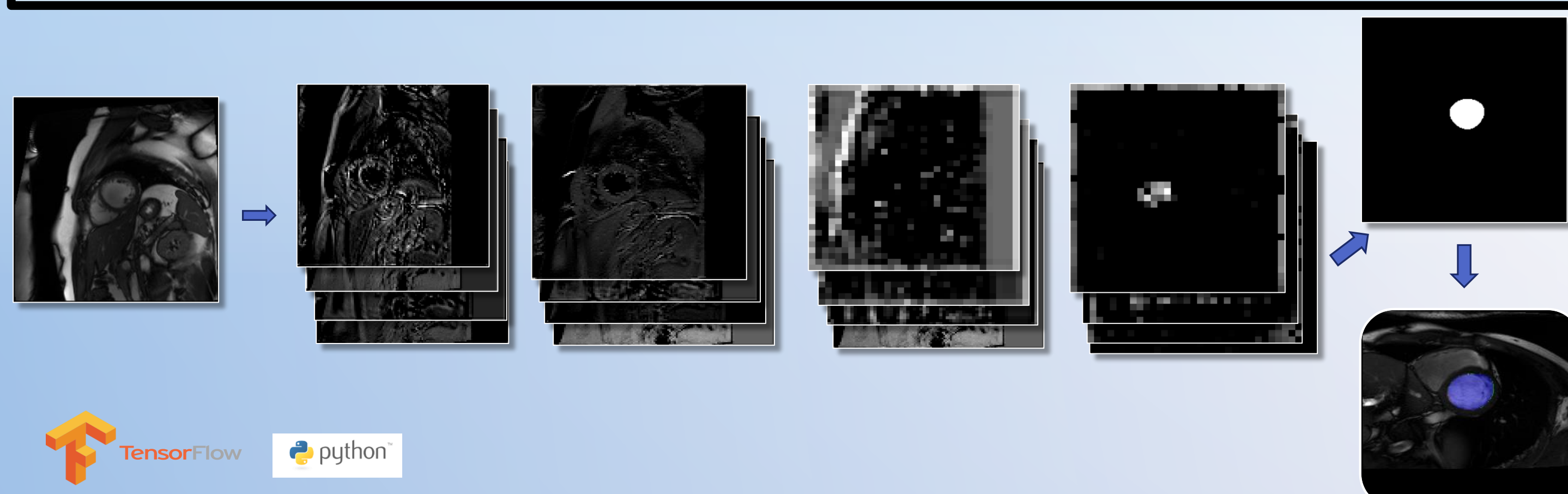
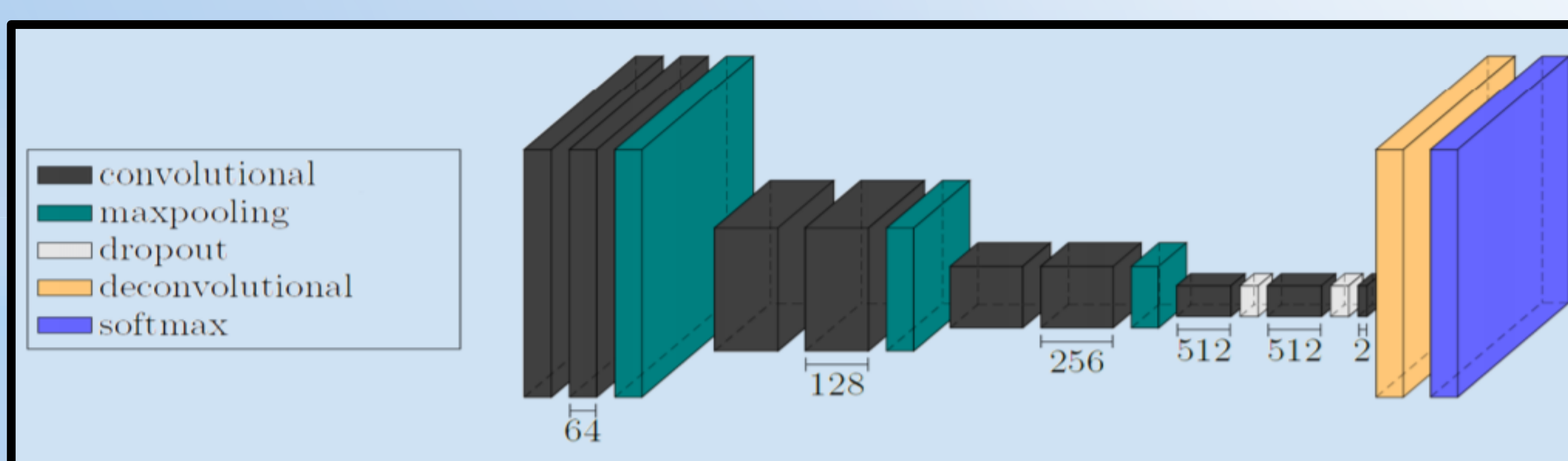


Data Pipeline

- We required a data pipeline to enable inference of clinical indices using the convolutional neural network.
- Available data consisted of >300,000 short axis cardiac images across ~1100 studies.
- Create generalizable code that can provide results for new data.

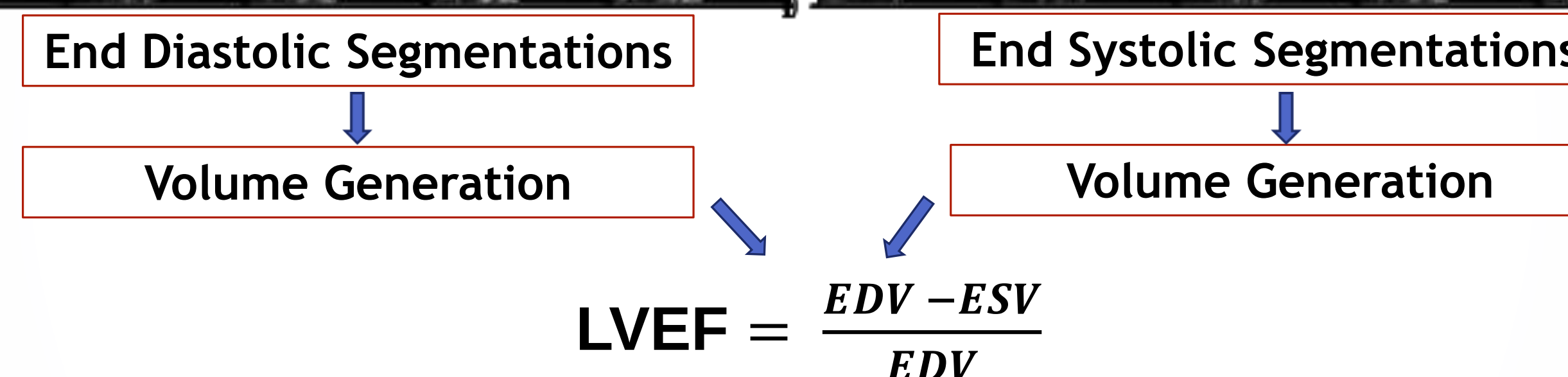
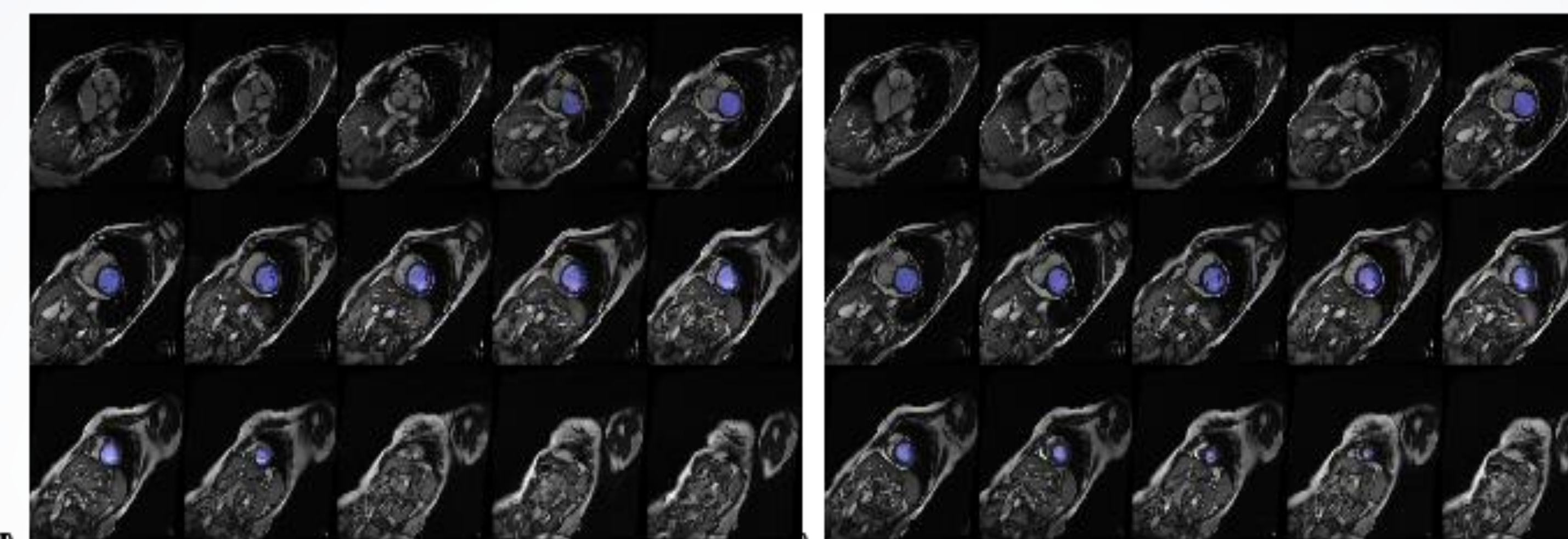


Convolutional Neural Network



Evaluation

- Needed to provide a comparison of LV indices inferred from the network and the indices from clinical records using a Bland-Altman plot.
- The Bland-Altman plot is a graphical method in which differences between data from two techniques is plotted against the means of the two techniques.
- Use segmentations from CNN to calculate indices as shown below.

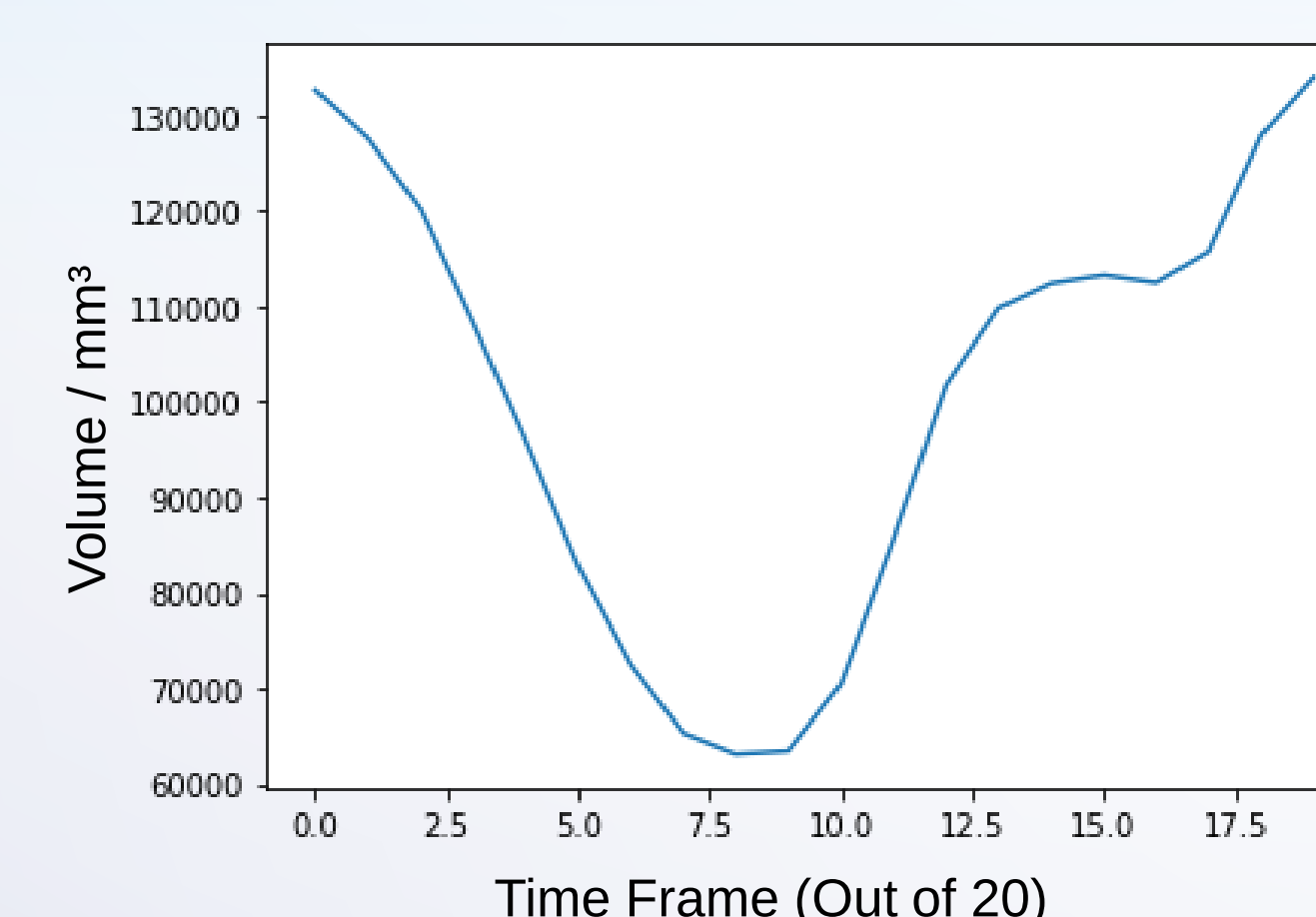


Volume Inference

- Create a module which will generate the volume for the study, regardless of the geometric slices and time frame
- Sort the segmented images from the network according to time frame and geometric slice.
- Accommodate and allow for spatial overlap between successive geometric slices, as well as spatial detachment.

The volume for a given time frame, t , is given below, with i denoting the current geometric slice for a total of n slices:

$$V(t) = \sum_{i=0}^{n-1} v_i(t)$$



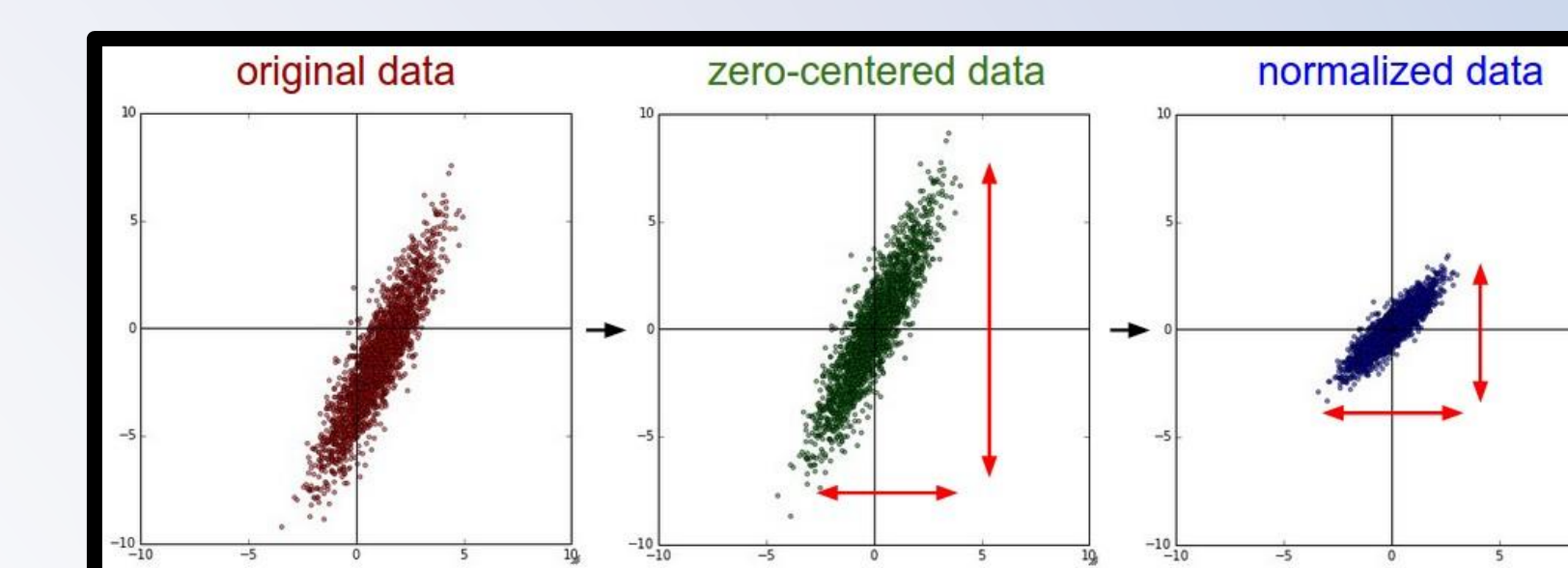
Volume of LV against time frame for a particular study

The volume for geometric slice i is given as:

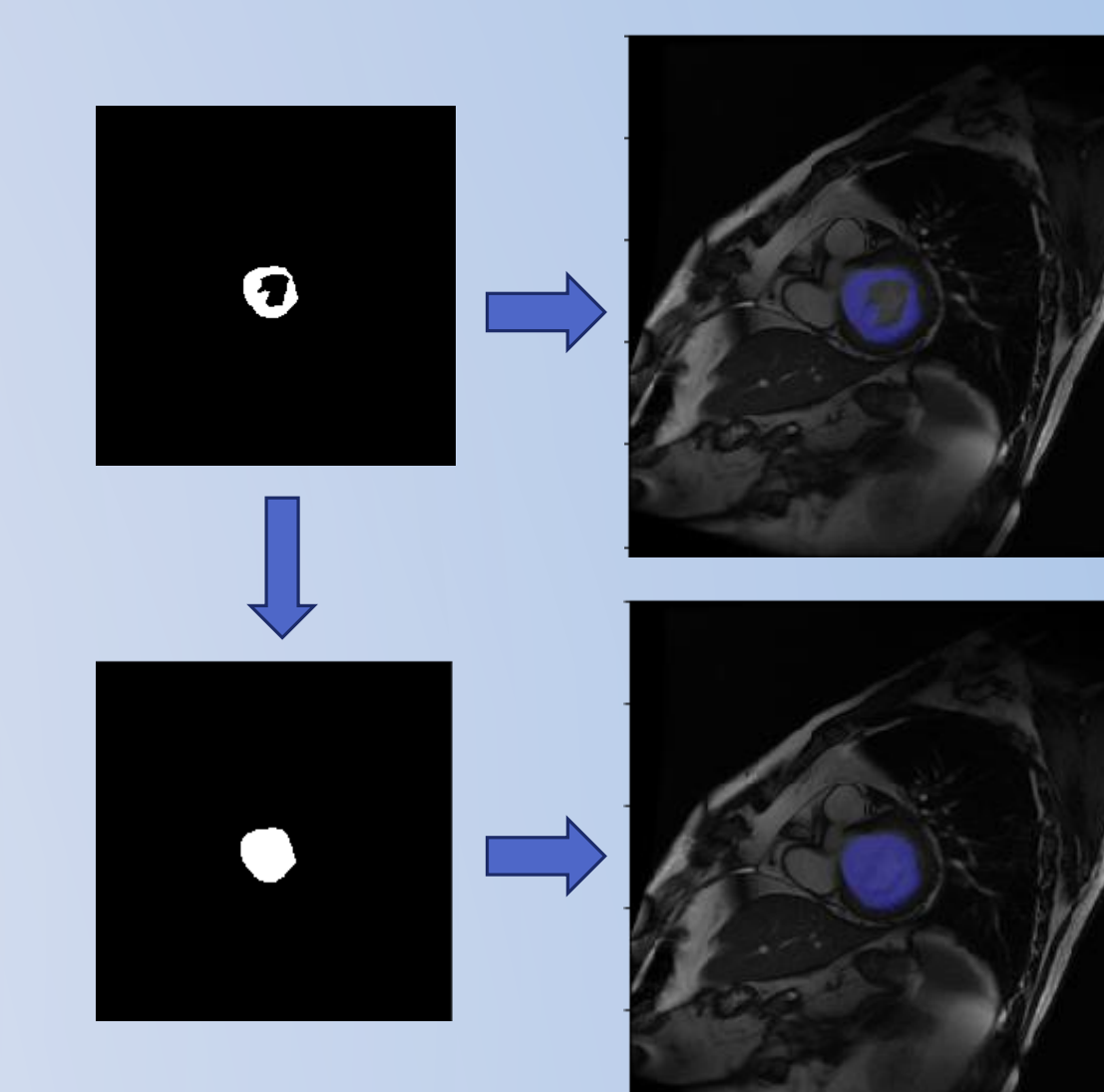
$$v_i(t) = \begin{cases} (T - |d_i - d_{i-1}|) \cdot A_i, & A_{i-1} > 0 \\ T \cdot A_i, & A_{i-1} \leq 0 \end{cases}$$

Here, T denotes the slice thickness common to the particular study, d_i is the slice location, and A_i is the area of segmentation calculated using pixel resolution.

Image Processing



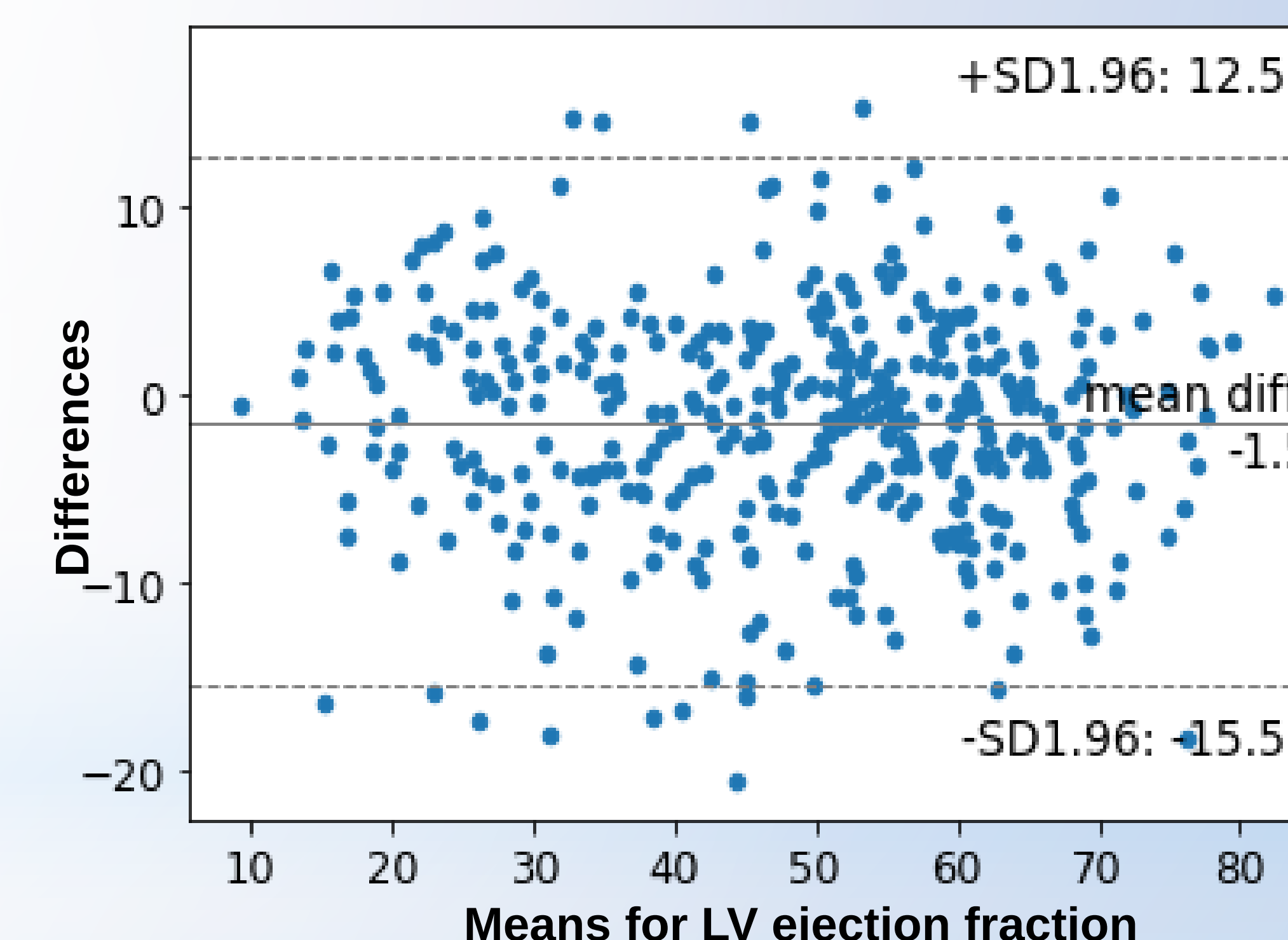
Mean Variance Normalization



Morphological closing

- Mean variance normalization: First, by subtracting the mean, we center the cloud of data around the origin along every dimension. Secondly, we normalize the data dimensions so that they are of approximately the same scale.
- Morphological closing: Fills in holes created during segmentation.

Results



- CNN shows low bias in left ventricle ejection fraction estimation.
- 14.7% of automated estimates within 5 % of manually recorded index.
- Large range of differences indicate clinical data differs significantly from training data.

Discussion / Future Plans

- Produce a manually contoured dataset from the Geisinger database of cardiac MRs and train the network along with a K-fold cross-validation scheme.
- Use a three dimensional neural network with two label conditional random field (CRF) [Kamnitsas et al. Feb 2017] for post-processing.

References / Acknowledgements

- Geisinger Dept. of Imaging Science and Innovation (Joshua Stough, Christopher Haggerty, Linyuan Jing, David Vanmaanen, Brandon Fornwalt)
- J.V. Stough, J. DiPalma, Z. Ma, B.K. Fornwalt, C.M. Haggerty. "Ventricular segmentation and quantitative assessment in cardiac MR using convolutional neural networks." SPIE-Medical Imaging 2018