Translating images into graphs: hybrid graph convolutional neural networks for landmark-based anatomical segmentation

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Abstract

- In this work we address the problem of landmark-based segmentation for anatomical structures.
- We propose **HybridGNet**, an encoder - decoder neural architecture which combines standard convolutions for image feature encoding, with graph convolutional neural networks to decode plausible representations of anatomical structures.
- We benchmark the proposed architecture considering other standard landmark and pixel-based models for anatomical segmentation in chest x-ray images, and found that HybridGNet is more robust to image occlusions. We also show that it can be used to construct landmark-based segmentations from pixel level annotations.
- Our experimental results suggest that HybridGNet produces accurate and anatomically plausible landmark-based segmentations, by naturally incorporating shape constraints within the decoding process via spectral convolutions.

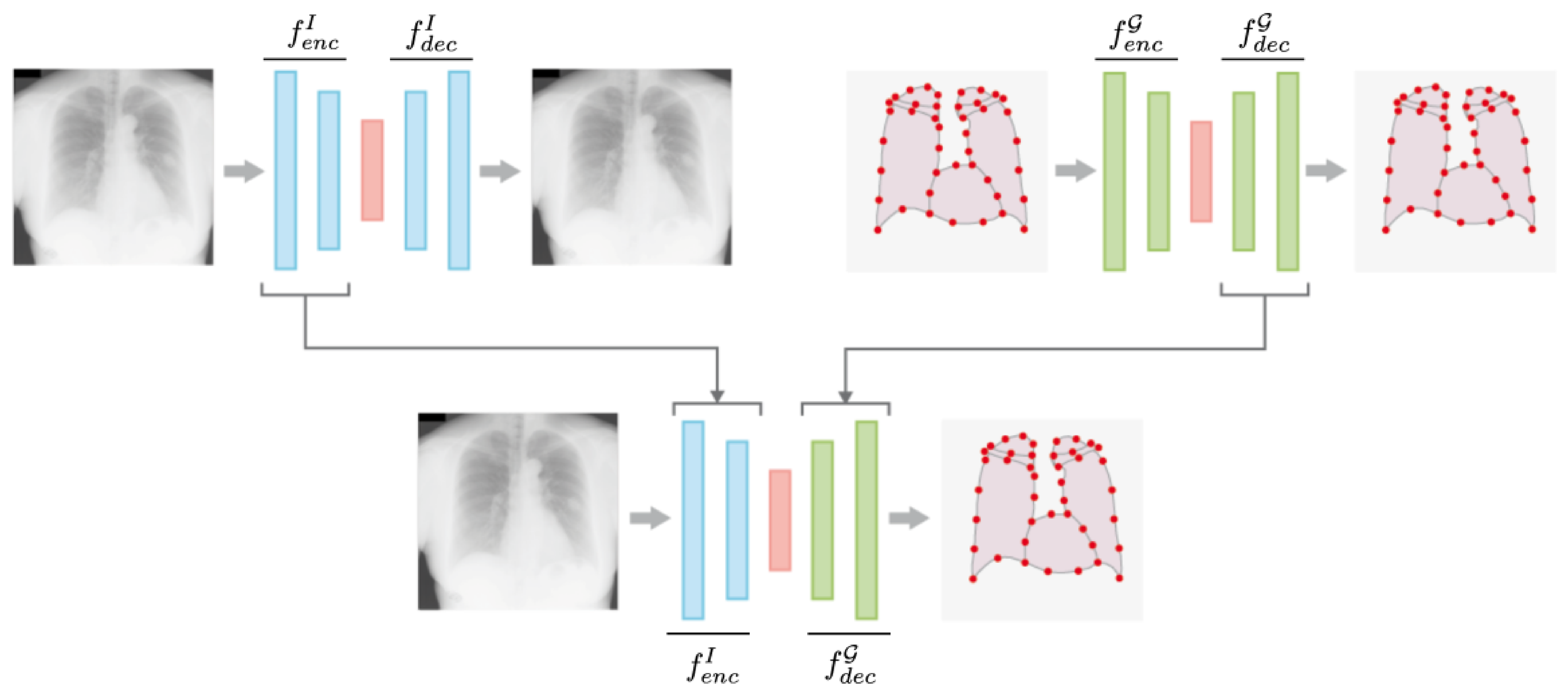

Figure 1: The proposed HybridGNet (bottom) is an encoder-decoder architecture which combines standard convolutions for image feature encoding (blue), with graph spectral convolutions (green) to decode plausible anatomical graph-based representations.

Methods

- **Problem setting:** We have dataset $\mathcal{D} = \{(I, \mathcal{G})\}$, composed of 2D images I and their corresponding landmark-based segmentation represented as a graph $\mathcal{G} =< V, \mathbf{A}, \mathbf{X} >$. V is the set of nodes (landmarks), $\mathbf{A}$ is the adjacency matrix indicating the connectivity between pairs of nodes and $\mathbf{X}$ is a function assigning a feature vector to every node. In our case, it assigns a 2-dimensional spatial coordinate to every landmark.
- **Assumptions:** For all graphs, we assume that the set of nodes (landmarks) and the connectivity matrices are the same.
- **Graph Variational Autoencoder**: Under the previous assumption, we trained a convolutional graph variational autoencoder, which consists of spectral convolutions using filters defined with Chebyshev polinomials, to learn latent representations of anatomy.
- **Hybrid model:** Our proposed HybridGNet combines the encoder branch of a classic convolutional autoencoder (for feature image encoding) with the decoder branch of the graph autoencoder.
- **Dual models:** Based on the HybridGNet model, we incorporated a second decoder which outputs dense segmentation masks. We tested it with (**Dual SC**) and without (**Dual**) convolutional skip connections.

Anatomical landmark-based segmentation.

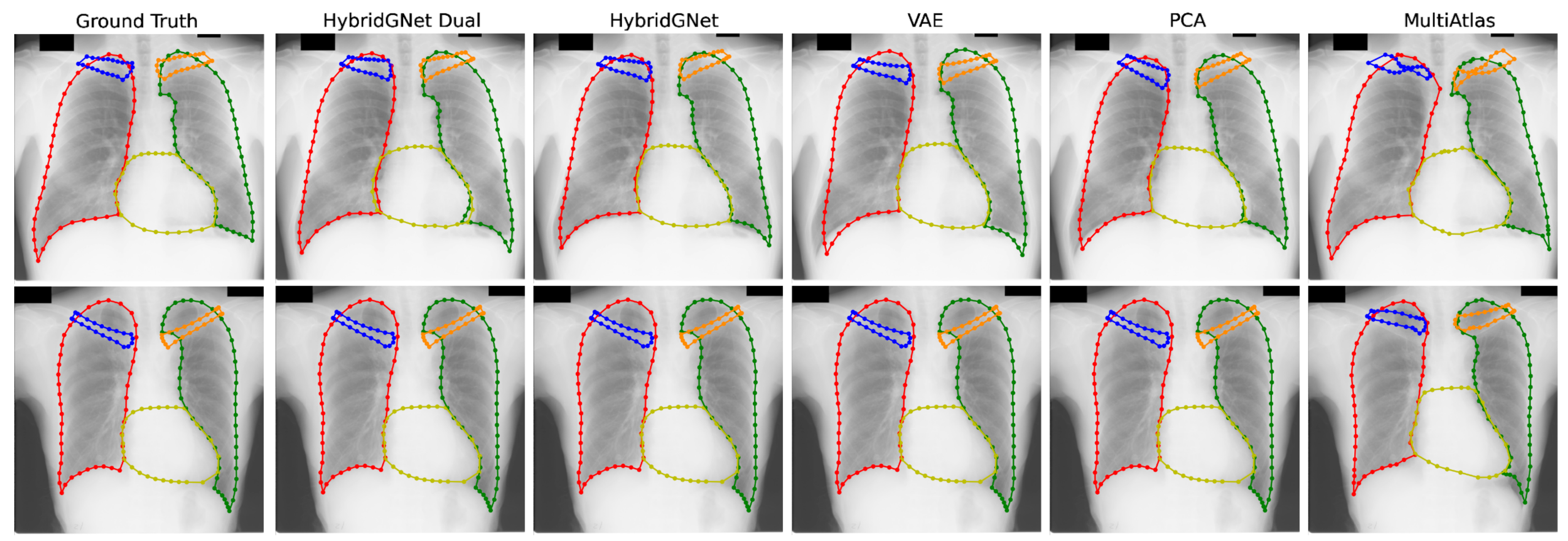

Figure 2: Qualitative results reflecting the improvement in anatomically plausibility obtained when using the HybridGNets (particularly in the clavicles which are the most challenging).

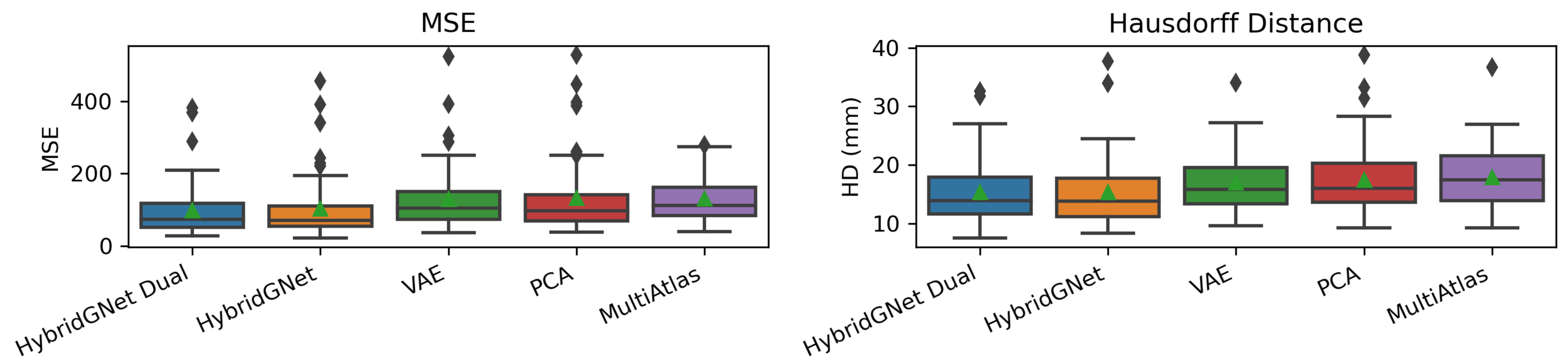

Figure 3: Quantitative results.

Generating landmark-based representations.

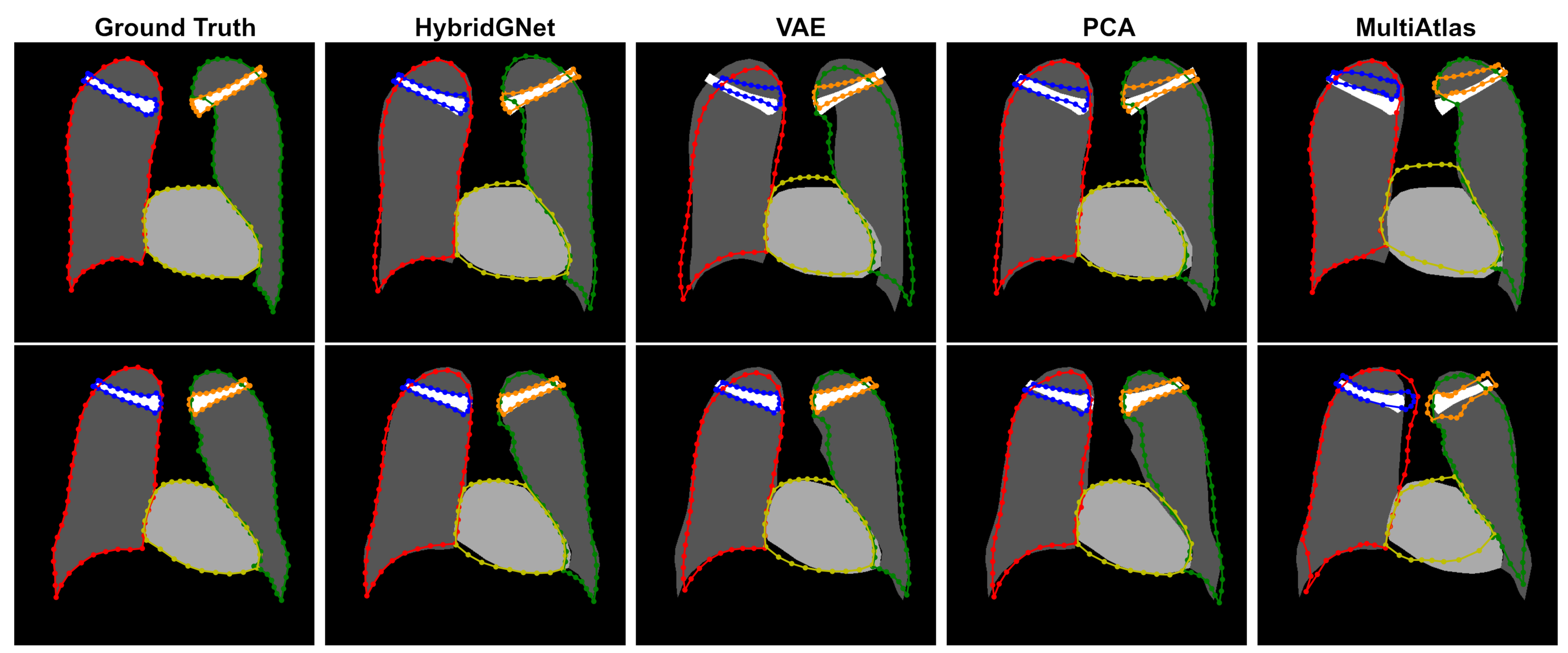

Figure 4: Examples of landmark-based representations generated from dense segmentation masks

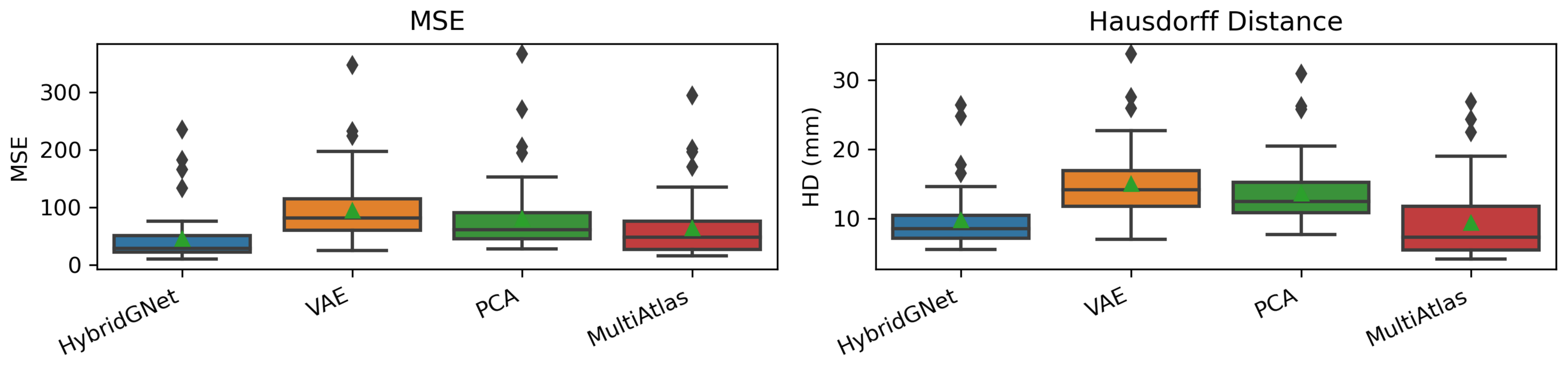

Figure 5: Quantitative results.

Robustness study.

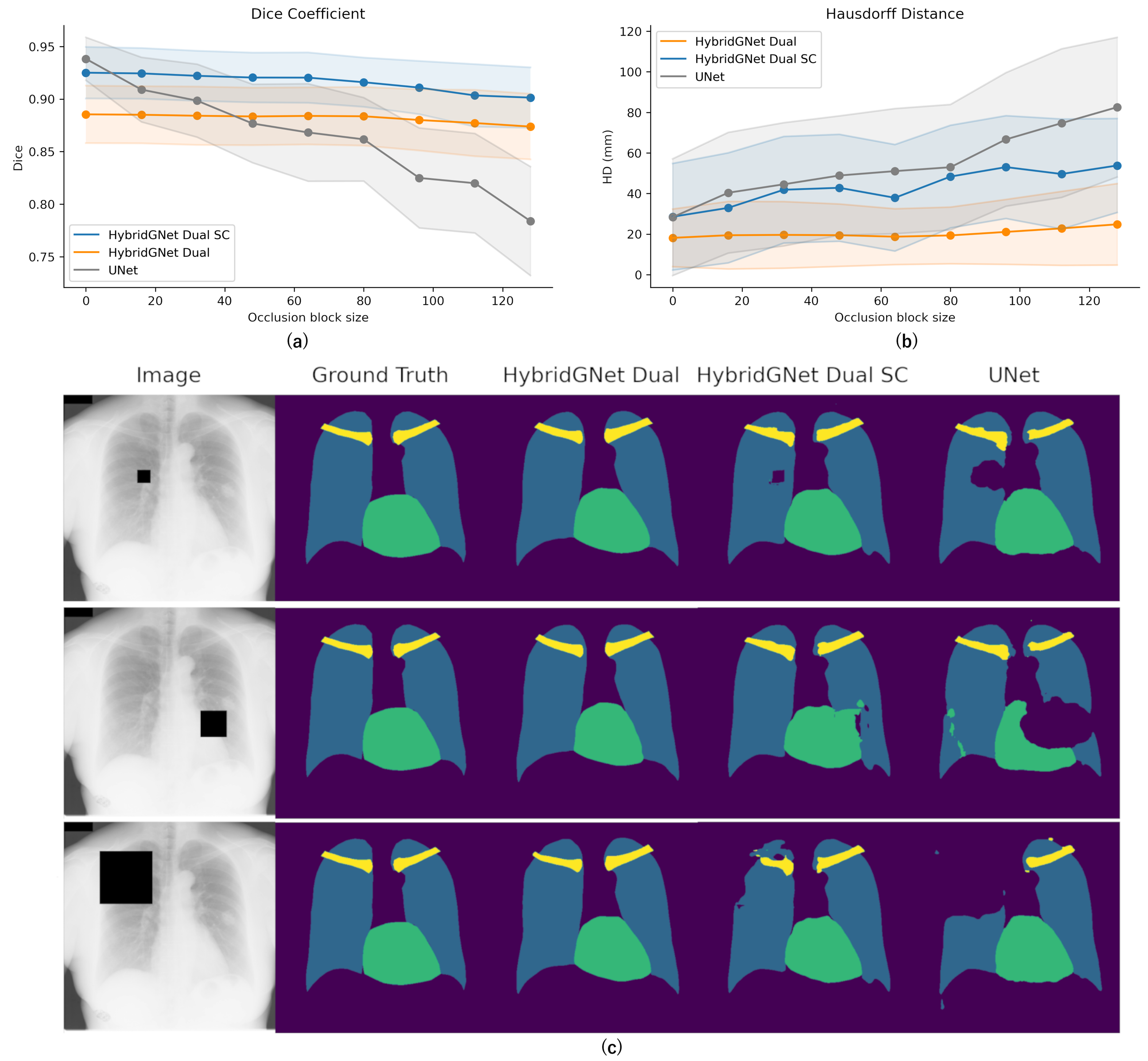

Figure 6: Figures (a), (b) and (c) show quantitative and qualitative results for the Experiment 3 (oclussion study). We can see that the HybridGNet Dual models are much more robust to missing parts than a standard UNet model.

Conclusions

- We show that incorporating connectivity information through the graph adjacency matrix helps to improve the accuracy of the results when compared with other landmark-based models which only employ vectorized landmark representations.
- We show it can be used to generate landmark-based anotations from pixel-level segmentations without paired images.
- We showcased different application scenarios for the HybridGNet and confirm that it is robust to image occlussions, in contrast to standard dense segmentation methods which tend to fail in this task.

Reference:

Gaggion, N., Mansilla, L., Milone, D., & Ferrante, E. (2021). Hybrid graph convolutional neural networks for landmark-based anatomical segmentation. `https://arxiv.org/abs/2106.09832` (Accepted at MICCAI 2021 Conference)

GitHub Repo:
`https://github.com/ngaggion/HybridGNet`

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