An Auto-Encoder Strategy for Adaptive Image Segmentation

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Challenge

- Annotations costs time, money and requires expertise
- Weeks to manually label a dataset
- Growing segmentation protocol or imaging technology
- **Objective**: Segmentation framework with one manual segmentations or labels

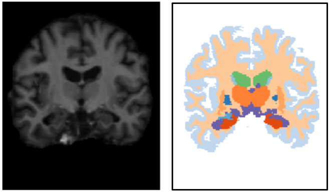


Figure 1: Structural brain MRI and its delineation

Setup

- Consider a dataset of N MRI scans $\{\boldsymbol{x}^{(i)}\}_{i=1}^{N}$
- Let $\boldsymbol{s}$ be latent segmentation
- By Bayes' rule:

$$\log p(\boldsymbol{x}^{(i)}) = \log \sum_{\boldsymbol{s}} p(\boldsymbol{x}^{(i)}|\boldsymbol{s})p(\boldsymbol{s}), \tag{1}$$

- Evidence Lower Bound (ELBO):

$$\begin{aligned} \log p(\boldsymbol{x}^{(i)}) \geq & - \mathrm{KL}(q(\boldsymbol{s}|\boldsymbol{x}^{(i)})||p(\boldsymbol{s})) \\ & + \mathop{\mathbb{E}}_{\boldsymbol{s}\sim q(\boldsymbol{s}|\boldsymbol{x}^{(i)})} \left[\log p(\boldsymbol{x}^{(i)}|\boldsymbol{s})\right]. \end{aligned} \tag{2}$$

Segmentation Autoencoder (SAE)

- Variational Autoencoder (VAE)

$$\mathcal{L} = \mathsf{KL}(q_\phi(\boldsymbol{s}|\boldsymbol{x}^{(i)})||p(\boldsymbol{s})) - \mathop{\mathbb{E}}_{\boldsymbol{s}\sim q_\phi(\boldsymbol{s}|\boldsymbol{x}^{(i)})}\left[\log p_\theta(\boldsymbol{x}^{(i)}|\boldsymbol{s})\right]. \quad (3)$$

- Typical VAE uses representation $\boldsymbol{s}$ that is typically continuous
- **Our model** maps $\boldsymbol{s}$ to a semantic meaningful representation:

$$q_\phi(\boldsymbol{s}|\boldsymbol{x}^{(i)}) = \prod_{j=1}^{V} \mathsf{Cat}(s_j|\boldsymbol{x}^{(i)}, \phi). \quad (4)$$

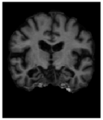
- Likelihood:

$$p_\theta(\boldsymbol{x}|\boldsymbol{s}) = \prod_{j=1}^{V} \mathcal{N}(\boldsymbol{x}; \hat{\boldsymbol{x}}_j(\boldsymbol{s};\theta), \sigma^2). \quad (5)$$

- Spatial Prior

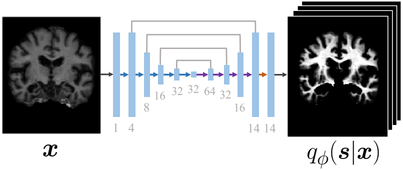
$$p_{spatial}(\boldsymbol{s}) = \prod_{j=1}^{V} p_j(s_j). \quad (6)$$

Architecture

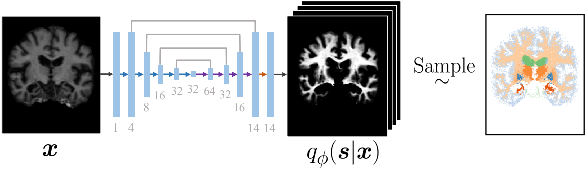


$\boldsymbol{x}$

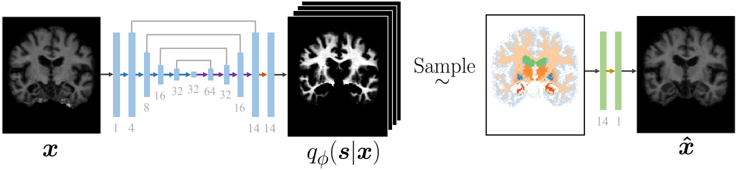
Architecture



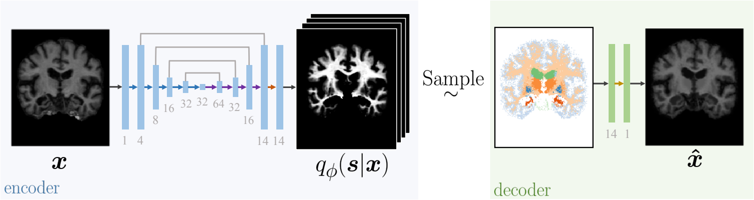
Architecture



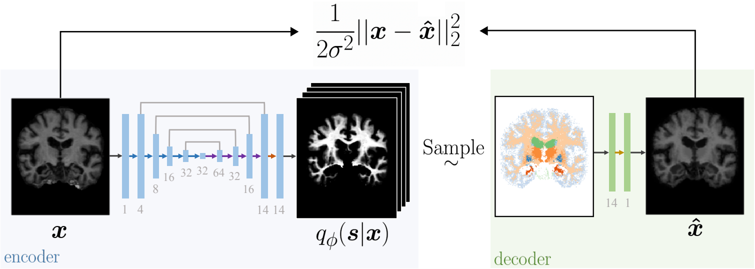
Architecture



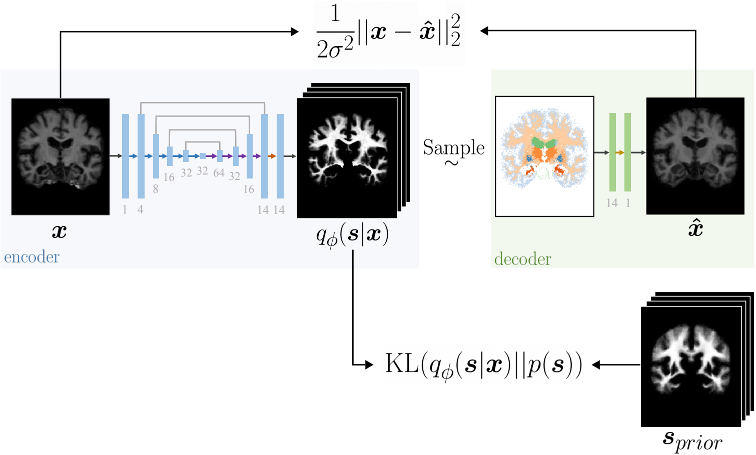
Architecture



Architecture



Architecture



Evaluation

- Buckner dataset
- T1 MRI scans and 12 manual labels
- 1 probabilistic label atlas
- 30 training subjects and 8 testing subjects
- Repeated the experiment 5 times with different random subject assignments to the train/test partitioning.

Qualitative Results

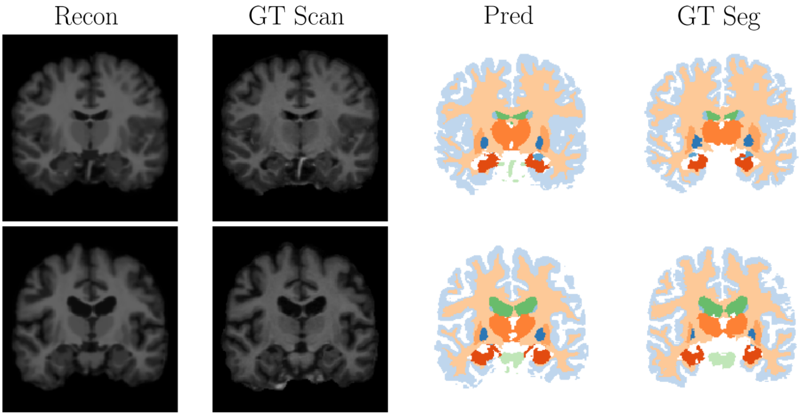


Figure 2: Representative segmentation results obtained with SAE (w/ MRF) on two subjects.

Quantitative Results

	Performance Measure	
Model	Haussdorff (mm)	Dice Overlap (%)
Baseline	3.50±0.06	71.45±0.65
EM Baseline	2.65±0.05	79.70±0.54
SAE (w/o MRF)	2.73±0.04	79.94±0.34
SAE (w MRF)	2.68±0.05	80.54±0.36
Supervised	2.23±0.07	84.60±0.26

Table 1: Mean performance of all methods with their standard errors.

Thank You

More experiments + Implementation:

https://github.com/evanmy/sae