Healthcare Innovations
How practice has changed

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SAMASK: Explainability of Deep CNN brain volumetric measurement using Smooth Attention MASK

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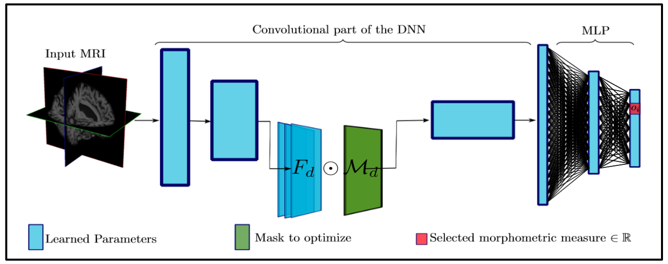
MOTIVATION AND GOAL

- **SAMASK** (**S**mOoth **A**ttention **MA**sk) is **an optimization method** that reveals the specific regions of the input image considered by the prediction of a trained neural network for **brain morphometric measurement**.
- SAMASK performs **saliency analysis** for complex **regression** tasks for **3D medical image** with deep convolutional neural networks.
- SAMASK optimizes an attention mask **at a given layer** of a convolutional neural network (CNN) in **40secondes**.
- This attention mask is point-wise multiplied for all the features at a certain depth of the CNN, we wish to find a mask that yields a minimal prediction error, and which is spatially smooth given a limited L^2 budget.
- SAMASK can help to identify **neural network's limitations** when cases are underrepresented as cases with large volume asymmetry.

METHOD



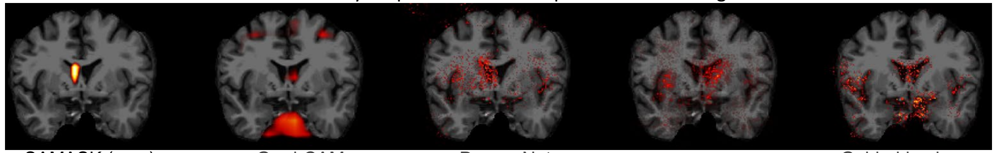
- Given a feature map F_d at a depth d of dimension $L_d \times H_d \times W_d \times D_d$, we **element wise multiply** F_d with a mask M_d of dimension $1 \times H_d \times W_d \times D_d$. We then pass the masked feature map $F_d \odot Md$ **through the remaining layers** of the network. The modified predictions $\boldsymbol{DNN_{M_d}}$ is therefore obtained for a **selected brain morphometric measurement** output o_i. Finally, we **upsample the mask $\boldsymbol{M_d}$** to the size at the input image.
- Given a fixed L^2 budget $\|M_d\|_2 = 1$, we find a mask M_d such that the prediction after masking the feature map DNN_{Md} is as close as possible to its original value DNN. We add a regularization term $\mathcal{R}_s$ that promotes spatial smoothness of the mask:

$$\arg\min_{M_d} \boldsymbol{d}\left(DNN_{M_d}, DNN\right) + \lambda \mathcal{R}_{\|\cdot\|_2}(Md) + \gamma \mathcal{R}_s(M_d),$$

with **d** the normalized distance, σ the standard deviation of the output measurement. γ and λ two hyper-parameters.

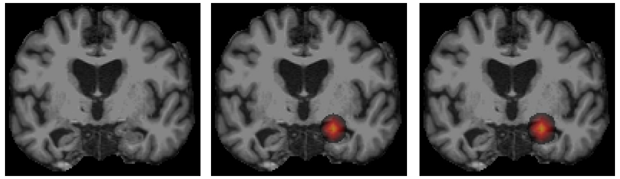
RESULTS

Different methods of saliency maps for the volume prediction of the right lateral ventricle



SAMASK (ours) | Grad-CAM | DeconvNet | Gradient saliency | Guided backprop

Attention map for the prediction of both hippocampi for a patient with large asymmetry



Patient with large asymmetry of the hippocampi 1.12cm³(left), attention mask for the right hippocampus volume (middle), attention mask for left hippocampus volume (right).

CONCLUSION

- SAMASK performs a quantitative analysis of brain morphometric measurements by optimizing the mask for brain parcellation volumes and intersecting the generated attention map with all brain regions to obtain their respective attention.
- SAMASK produces localised attention maps relatively fast for 3D regression models.
- For predicting a volume, SAMASK can highlight the region of interest as well as its neighbour regions.
- Our approach can be used to detect some limitations of end-to-end deep-learning models like its poor performance on anatomical areas where the data is under-represented.