MA Thesis: Quantifying Trust of Segmented Pathologies in Brain Imaging with little supervision

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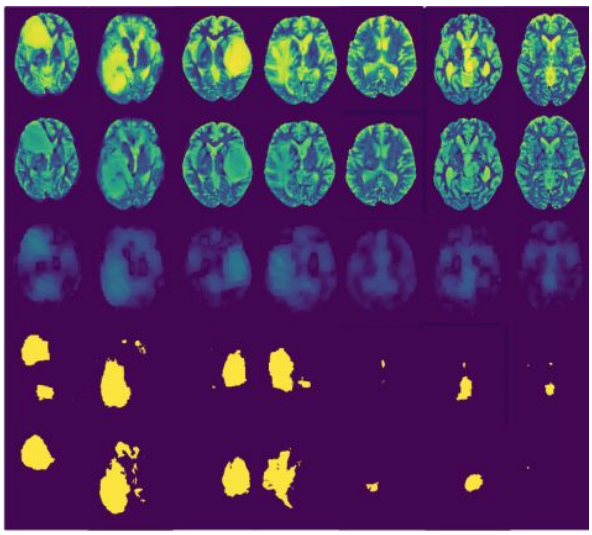

Abstract. Detecting general anomalies, i.e. anomalies of all types, has been a challenging task in medical applications. Current state-of-the-art (SOTA) methods solve this in an unsupervised way by investigating the restoration of images [1, 5] or latent representations [6] of Variational Autoencoders (VAEs). However, problems during the detection stage are not yet addressed, such as domain shift caused by different imaging devices and parameters. In such cases, the detection outcome is in fact less trustable and should give an uncertainty measure in practical application. Therefore, it's desired that the out-of-distribution (OOD) regions caused by pathological anomalies and domain shift are distinguished by the model. We would like to explore an adjacent line of research that detects image-level out-of-distribution (OOD) samples and combine it with the current SOTA method. The goal of this thesis is to merge both lines of work, in order to develop a novel approach that can detect anomalous regions in image data while quantifying the trust in its predictions using OOD detection. To realize this, you will train your model on healthy MR brain imaging data, and test the model on MR brains with pathology, i.e. Multiple Sclerosis Lesions, Tumors, and Strock.

Roadmap:

- Familiarize yourself with the current literature on Anomaly detection [8].
- Implement anomaly detection in image space [1, 6] and understand its limitations w.r.t. OOD detection.
- Implement OOD detection based on density models in the latent space of a VAE [3]
- Merge both approaches and evaluate resulting performance. Can metrics on individual tasks be improved by a combined approach?

If you are interested in this project, please write an email to salbarqouni@ethz.ch, jpostels@ethz.ch, chenx@vision.ee.ethz.ch

Research Questions:

Q1) Can we detect pathologies in brain imaging using a semi-supervised learning paradigm?
Q2) Restoration methods? Latent space (7) or Image Space (1)?
Q3) OOD Uncertainties? Anomalies vs. Domain Shift?!

Requirements:

- Solid background in Machine/Deep Learning
- Familiar with generative models, AEs, VAEs, ...etc.
- Sufficient knowledge of Python programming language and libraries (Scikit-learn, NumPy, ...)
- Experience with a mainstream deep learning framework such as PyTorch or Tensorflow.
- Machine/Deep learning hands-on experience

References:

[1] Dehaene, D., Frigo, O., Combrexelle, S. and Eline, P., 2020. Iterative energy-based projection on a normal data manifold for anomaly localization. *ICLR 2020*. (PDF)
[2] Ruff, L., Vandermeulen, R.A., Görnitz, N., Binder, A., Müller, E., Müller, K.R. and Kloft, M., 2019. Deep semi-supervised anomaly detection. *ICLR 2020*. (PDF)
[3] Zong, B., Song, Q., Min, M.R., Cheng, W., Lumezanu, C., Cho, D. and Chen, H., 2018. Deep autoencoding gaussian mixture model for unsupervised anomaly detection. (PDF)
[4] Kim, K., Shim, S., Lim, Y., Jeon, J., Choi, J., Kim, B., Yoon, A., 2020. Rapp: Novelty Detection With Reconstruction Along Projection Pathway. *ICLR 2020* (PDF)
[5] You, S., Tezcan, K., Chen, X. and Konukoglu, E., 2018. Unsupervised lesion detection via image restoration with a normative prior. *MIDL 2019* (PDF)
[6] Chen, X. and Konukoglu, E., 2018. Unsupervised detection of lesions in brain mri using constrained adversarial auto-encoders. *MIDL 2018* (PDF)
[7] Schlegl, T., Seeböck, P., Waldstein, S.M., Langs, G. and Schmidt-Erfurth, U., 2019. f-AnoGAN: Fast unsupervised anomaly detection with generative adversarial networks. *Medical image analysis*, *54*, pp.30-44. (PDF)
[8] Baur, C., Denner, S., Wiestler, B., Albarqouni, S. and Navab, N., 2020. Autoencoders for Unsupervised Anomaly Segmentation in Brain MR Images: A Comparative Study. *arXiv preprint arXiv:2004.03271*. (PDF)

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