Evidential Deep Learning for Glioblastoma and Intracranial Aneurysms Quantification in Neuroradiology

Master Thesis Proposal in Image Analysis and Machine Learning at the Division for Visual Information and Interaction, Department of Information Technology.

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Background

Uncertainty is the most common and unavoidable feature of DL tasks. DL models produce a point estimate, which is often incorrectly interpreted as a probability of model confidence. In reality, it is a normalized network output for a given class relative to the other classes. This cannot explain the model's overall confidence and leads to generalization issues, such as over-confidence in their predictions and unpredictable behavior on out-of-distribution (OOD) samples. For example, DL-based diagnosis of MRI images of brain tumours needs a way to express the uncertainty of an image in the same way as a doctor may express ambiguity and ask for experts help for further inspection and correction.

Therefore, it is not sufficient to depend on the classification or regression score alone from DL models. In order to address this problem, the deep neural networks need to provide uncertainty estimation as an additional insight to point prediction to improve the reliability in the decision-making process. Estimating uncertainty in deep neural networks is a challenging and yet unsolved problem. Bayesian neural networks (BNNs) learn a distribution over each of the network's weight parameters and are currently considered state-of-the-art for estimating predictive uncertainty. There are many methods proposed for quantifying uncertainty or confidence estimates approximated by Markov chain Monte Carlo (MCMC), variational inference (VI) including deep ensembles.

In medical image segmentation, a network can be certain with high or less confident about its decision, indicated by the predictive posterior distribution. However, predictive uncertainty in DL results from two separate forms of uncertainty viz. model uncertainty or epistemic uncertainty (EU) accounts for uncertainty in the model parameters due to the lack of training data. EU associated with the model reduces as the training data size increases. Data uncertainty or aleatoric uncertainty (AU) accounts for noise inherent in the observations due to class overlap, label noise, homoscedastic and heteroscedastic noise, which cannot be reduced even if more data were to be collected unless it is possible to observe all explanatory variables with increased precision.

Aim

Our objective is not to achieve the state-of-the-art performance for quantification of Glioblastoma and Intracranial Aneurysms from radio images like MRI, but rather to define a framework for estimating uncertainty in the DL based segmentation model and evaluate the usefulness of predictive uncertainty to avoid overconfident, incorrect predictions during decision making in computer-based medical systems.

Prerequisites

- Proficiency in computer programming (Python is a must).
- Extensive knowledge on deep learning environments (TensorFlow, Keras, and PyTorch) and GPU optimization.
- Background on statistical learning, parameter estimators, Bayesian Neural Networks (BNNs), CNNs, GANs, VAEs.
- Experience in medical imaging physics and analysis (e.g., MRI, CT) is preferable.

References

1. Sensoy, M., Kaplan, L. and Kandemir, M., 2018. Evidential deep learning to quantify classification uncertainty. arXiv preprint arXiv:1806.01768.
2. Amini, A., Schwarting, W., Soleimany, A. and Rus, D., 2020. Deep evidential regression. Advances in Neural Information Processing Systems, 33.
3. Ghoshal, B., Tucker, A., Sanghera, B. and Lup Wong, W., 2021. Estimating uncertainty in deep learning for reporting confidence to clinicians in medical image segmentation and diseases detection. Computational Intelligence, 37(2), pp.701-734.