# Uncertainty quantification using Bayesian neural networks in classification: Application to ischemic stroke lesion segmentation

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Most recent research of neural networks in the field of computer vision has focused on improving accuracy of point predictions by developing various network architectures or learning algorithms. While they have shown outstanding performances in many different computer vision tasks, less attention has been paid to assessing uncertainty in neural network outputs. Probabilistic interpretations via uncertainty quantification are important because (1) absences of sufficient understanding of model outputs may provide suboptimal results and (2) neural networks are subject to overfitting, so making decisions based on point prediction alone may provide incorrect classifications with spuriously high confidence.

In medical imaging applications, assessment of uncertainty could potentially reduce untoward outcomes due to suboptimal decisions. In this paper, we invoke a Bayesian neural network and propose a natural way to quantify uncertainty in classification problems by decomposing predictive uncertainty into two parts, aleatoric and epistemic uncertainty. The proposed method takes into account discrete nature of the outcome, yielding correct interpretation of each uncertainty. We demonstrate that the proposed uncertainty quantification method provides additional insight to the point prediction using images from the Ischemic Stroke Lesion Segmentation Challenge.

Our main contributions of this paper are:

1. We propose a new method of quantifying uncertainties in classification using Bayesian neural networks. Our method exploits the relationship between the variance and the mean of a multinomial random variable and avoids estimation of extra parameters for the variance.

2. We demonstrate the proposed method using the two Ischemic Stroke Lesion Segmentation Challenge (ISLES) datasets with different effective sample sizes. Our results demonstrate interpretable uncertainty maps, and exhibit dependence between the epistemic uncertainty and the effective sample size.