Project plan:
Quantifying Uncertainty in Semantic Segmentation using Bayesian Deep Metric Learning

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Within the field of computer vision, image segmentation is the art of partitioning an image (or sequences of images in videos) into different segments, where the overall goal is to simplify the representation of the image to something much easier to analyse - at least for computers. Image segmentation today is being used in a great variety of areas such as medical imaging, facial recognition, self-driving cars, traffic control, and many more[ImS].

In earlier days, computer vision, in general, relied on researchers manually deriving convolutions/algorithms e.g. detecting object edges and other image-specific features, to represent the images in a meaningful way for computers could start finding patterns - and from there take actions or make recommendations. These analyses could be quite complicated and time-consuming and they were thus not very feasible for application outside research[CVH].

It was later discovered that neural networks provided an automatic way for feature extraction on images - they could learn the convolution directly from data. We call these types of neural networks for Convolutional Neural Networks (CNNs). However, they posed a great issue, namely that they were very time-consuming to train.

Then in 2012, a breakthrough happened within computer vision when the Deep Learning model AlexNet (also with a CNN structure) achieved a top-5 error rate of 15.3% in the ImageNet Large Scale Visual Recognition Challenge (ILSVRC), more than 10.8% better than the second place[Ale]. AlexNet was trained using GPUs, which greatly reduced the issue of time-consuming training. This was not the first model to train CNNs on GPUs, but it was the first deep neural network (DNN) to enter ILSVRC. This result spiked the hope for using AI (and hence computer vision) in more applicable areas[CVH].

However, there is a downside to the great predictive performance that DNNs have. They do not inherently provide us with any uncertainty quantification on the predictions. This might not be a significant problem in areas where faulty predictions do not result in any catastrophes. However, within specific applications it can be quite imperative to have confidence measures on those predictions, like for self-driving cars: is the object moving onto the road a kid or a balloon? If the best prediction is a balloon, but the model is almost as sure that it could be a kid, the car should stop before impact! Just in case.

This project aims to mitigate this deficiency by considering a Bayesian approach to Deep Learning. To better grasp this overall problem, the focus is narrowed down to a specific use case within DL, namely Semantic Segmentation, which for instance is being used for self-driving cars. We will start out building a Bayesian-based image classification model using Bayesian Deep Metric Learning, which hopefully should provide well-calibrated uncertainties on those classifications.

This model will then be the foundation for our Bayesian semantic segmentation model. It will be a two-way framework: first, for an image we get object proposals from the COB model on different scales (granularities)[MPTAG17], these will each be classified using the Bayesian image classification model, and then for each pixel in each proposal the classification probabilities and uncertainties will be accumulated to one discrete probability distribution over the classes. This should provide a quantification of the uncertainty in the semantic segmentation at a pixel level.

References

[Ale] Alexnet - wikipedia. https://en.wikipedia.org/wiki/AlexNet. Accessed: 2022-09-14.

[CVH] How artificial intelligence revolutionized computer vision: A brief history - motion metrics. https://www.motionmetrics.com/how-artificial-intelligence-revolutionized-computer-vision-a-brief-history/. Accessed: 2022-09-14.

[ImS] Image segmentation - wikipedia. https://en.wikipedia.org/wiki/Image_segmentation. Accessed: 2022-09-14.

[MPTAG17] Kevis Kokitsi Maninis, Jordi Pont-Tuset, Pablo Arbeláez, and Luc Van Gool. Convolutional oriented boundaries: From image segmentation to high-level tasks. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 40:819–833, 1 2017.

Master Thesis: Quantifying ...	start	end	14%
Litteratur Review and Initial work	**21/08/22**	**17/09/22**	**100%**
Find, read, and summaries relevant ...	21/08	10/09	100%
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Hand in Project-plan (planned date)	16/09	16/09	100%
Build classifier model framework	**11/09/22**	**15/10/22**	**11%**
Set up entire project structure (Cook...	11/09	17/09	50%
Get an understanding of the data str...	11/09	24/09	25%
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Build and train initial Bayesian classif...	18/09	15/10	0%
Analyze classifier model results	**09/10/22**	**22/10/22**	**0%**
Make classifier class in python (e.g. f...	09/10	22/10	0%
Make calibration plots, mAP estimate...	09/10	22/10	0%
Build Semantic Segmentation fram...	**16/10/22**	**05/11/22**	**0%**
Understand COB model and structure...	16/10	29/10	0%
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