Hochschule
Bonn-Rhein-Sieg
University of Applied Sciences

b-it Bonn-Aachen International Center for Information Technology

R&D Project Proposal

Simulation based evaluation of uncertainty estimation

Sathwik Panchangam

Supervised by

Prof. Dr. Nico Hochgeschwender
MSc. Deebul Nair

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1 Introduction

- Basic neural networks provide only predictions and do not deliver uncertainty estimates and they suffer from over or under confidence [4].
- Inabilities like providing reliable uncertainty estimates, over confident predictions, distinguishing between in-domain and out-of-domain samples can be considered as some of the examples for the limitations of deploying Deep neural networks (DNN)s in real world applications and safety critical systems like Robotics and medical image analysis etc [4].
- Deep learning algorithms can be fully integrated into robotic systems only if a measure of prediction uncertainty is available.
- Making a wrong decisions in applications like self driving cars, autonomous systems and health care does not only result in the failure of the task but might even put human lives at risk.
- Also for a safe decision making, estimating the predictive uncertainty alone is not sufficient, but a good evaluation is required to check the quality of uncertainty estimates.

1.1 Problem Statement

- The quality of the uncertainty estimates mainly depends on the method used for estimating the uncertainty and also research shows that defining ground truth uncertainties is challenging and there is a lack of ground truth uncertainty estimates [4] [5].
- The main problem statement of this RnD project is, Can a simulation software like Blender be used as the ground truth for the evaluation of uncertainty estimation?
- For this we are interested to generate a data-set in an open source software blender [1] [2] by applying textures and providing necessary environment conditions to the cad designed objects present in YCB benchmark object data-set and Robocup@work components data-set.

- Using this generated data-set we would like to estimate the uncertainty and compare it with the real world data-set using single model approaches.
- One of the main focus of this RnD project is to estimate and compare the uncertainty of a real world data-set and a data-set generated from a simulation software(Blender).
- These uncertainty estimates are desired to be computed using single model approaches as they are computationally efficient in training and evaluation.
- This Rnd also focuses on estimating uncertainties using different DNN architectures like Resnet, MobileNet and SqeezeNet.
- Finally we would like to evaluate and compare the predicted uncertainties of different blender generated data-sets and the real world data-sets.

2 Related Work

- Uncertainty in a DNN is mainly caused due to the the lack of knowledge of the neural network which is termed as model uncertainty or epistemic uncertainty and the second is type of uncertainty is caused due the presence of uncertainty in the training data, which is termed as data uncertainty or aleatoric uncertainty.
- One of the most common way to estimate the predictive uncertainty is based on separately modelling the epistemic and aleatoric uncertainties.
- The current state-of-the-art methods uses Bayesian inference [3], ensembles [5], test time data augmentation [7] or single deterministic networks [6] to estimate the uncertainty of a prediction.
- Compared to the state-of-the-art uncertainty estimation approaches single model approaches are more computationally efficient in training and evaluation [4].

2.1 Single model approaches

- Within a deterministic network, single model approaches provide a prediction based on a single forward pass.
- Only one network can be used for training and often these approaches can even be applied on pre-trained networks.
- Depending on the actual approach, only a single or at most two forward passes have to be fulfilled for evaluation [4].

2.2 Blender for generating data-sets

- What have other people done in integrating blender with deep learning?
- How is blender used to generate data-sets.

3 Project Plan

3.1 Work Packages

The bare minimum will include the following packages:

WP1 Literature Search

- Literature search on single model approaches for estimating uncertainty in classification techniques.
- Literature search on evaluation methods for uncertainty estimation.
- Literature search on using blender for data-set generation.

WP2 Data set generation

- Designing cad models for the objects present in YCB benchmark object data-set and Robocup@work components data-set in blender.
- Texturing and environment setup of the cad models in blender for generating dataset.

- Generating data-set of textured objects in different environments and lighting conditions in blender.
- Generating data-set of objects with different textures on a same background or same environment conditions for both data sets.

WP3 Mid term report

WP4 Experiments

- Estimating uncertainty using the real world data-set of YCB benchmark objects and Robocup@work components with the help of single model approaches.
- Estimating uncertainty using the blender generated data-set of YCB benchmark objects and Robocup@work components with the help of single model approaches.
- Performing experiments of uncertainty estimation on Resnet, Mobilenet and squeeze net architectures for all the available datasets.
- Evaluation of the estimated uncertainties of both real world and blender generated datasets.

WP5 Project Report

- Documentation of the literature on uncertainty estimation using single model approaches.
- Documentation of data-set generation using blender.
- Documentation of estimating uncertainty for YCB benchmark object data-set and Robocup@work components data-set using single model approaches.
- Documentation of estimating uncertainty for Blender generated datasets of YCB benchmark objects and Robocup@work using single model approaches.
- Documentation of Evaluation of uncertainties for both cases.

3.2 Milestones

M1 Literature search

- Literature search on uncertainty estimation using single model approaches.
- Literature search on evaluation methods for uncertainty estimation.
- Literature search on using blender for data-set generation.

M2 Experimental setup

- Designing cad models for the objects present in YCB dataset and Robocup@work components dataset in blender.
- Texturing and environment setup of the cad models in blender for generating dataset.
- Generating data-set of textured objects in different environments and lighting conditions for both data-sets in blender.
- Generating data-set of objects with different textures on a same background or same environment conditions for both data sets in blender.

M3 Experimental Analysis

- Estimating the uncertainty for both real world data-sets using single model approaches.
- Estimating the uncertainty for blender generated data-set containing same object with different backgrounds or environments,using single model approaches.
- Estimating the uncertainty for blender generated data-set containing same background or environment and different textures,using single model approaches.
- Estimating these uncertainties on three different Deep Learning architectures Resnet, MobileNet and SqueezeNet.
- Evaluating and Comparing the uncertainty in all the cases.

M4 Report submission

- Documentation of Literature search on uncertainty estimation
- Documentation of Literature search on using blender for data-set generation.
- Documentation of data-set collection of real world data-set and blender generated data-set.
- Documentation on estimating uncertainty using single model approaches for both real world data sets.
- Documentation on estimating uncertainty using single model approaches for both blender generated data sets.
- Documentation the mid term report.
- Documentation of evaluation and Comparison of uncertainty between collected data-sets.
- Documentation of draft copy of RnD report.
- Documentation of Final RnD report.

3.3 Project Schedule

Simulation based evaluation of uncertainty estimation														
S.no	Tasks		Sub tasks	Start date	End date	15-May-22	15-Jun-22	15-Jul-22	15-Aug-22	15-Sep-22	15-Oct-22	15-Nov-22	15-Dec-22	15-Jan-23
1	Literature Search	1.1	Single model approaches.	15-May-22	15-Jun-22									
		1.2	Blender for data-set Generation.	15-Jun-22	30-Jun-22									
		1.3	Evaluation methods for uncertainty estimation.	01-Jul-22	31-Jul-22									
2	Data-set Generation	2.1	Design of cad models in blender.	15-May-22	30-May-22									
		2.2	Texturing and environment setup.	01-Jun-22	30-Jun-22									
		2.3	Generating data sets with same textures and different backgrounds.	01-Jul-22	15-Jul-22									
		2.4	Generating data sets with different textures and same background.	15-Jul-22	31-Jul-22									
3	Mid term report	3.1	Documentation of mid term report.	01-Aug-22	30-Sep-22									
4	Experiments	4.1	Working code for uncerainty estimation in pytorch.	01-Jul-22	15-Jul-22									
		4.2	Estimating the uncertainty using one of the data set and one DL architecture.	15-Jul-22	31-Jul-22									
		4.3	Estimating uncertainy for all the datasets using one DL architecture.	15-Sep-22	01-Oct-22									
		4.4	Performing experiments with other two DL architectures.	01-Oct-22	31-Oct-22									
		4.5	Evaluation of the performed experiments.	01-Nov-22	15-Nov-22									
5	Final Project report	5.1	Documentation of literature search.	15-Nov-22	30-Nov-22									
		5.2	Documentation of data-set generation.	01-Dec-22	07-Dec-22									
		5.3	Documentation of single model approaches.	08-Dec-22	14-Dec-22									
		5.4	Documentation of the code for estimating uncertainty.	15-Dec-22	21-Dec-22									
		5.5	Documentation of evaluation results and conclusions.	22-Dec-22	15-Jan-23									

Figure 1: Project Timeline

3.4 Deliverables

Minimum Viable

- Literature survey on estimating uncertainty using single model approaches.
- Literature survey on using blender for generating data-sets.
- Literature survey on evaluation methods for uncertainty estimation.
- Analysis of state of the art uncertainty estimation methods.
- Conducting experiments for estimating uncertainty using the state-of-the-art single model approaches on both real world data-sets and blender generated data-sets.

Expected

- Generating different data-sets by varying the textures and background conditions in blender.
- Estimating uncertainty for the real world data-sets and blender generated data-sets.
- Evaluation and Comparison of the estimated uncertainties for all the data-set and in three different deep learning architectures.

Desired

- Evaluation and Comparison of the estimated uncertainties for all the data-set and in three different deep learning architectures.
- Addressing the problem statement, Can a simulation software like Blender be used as the ground truth for the uncertainty estimation?

References

[1] Blender is free software. `https://www.blender.org/about/license/`.

[2] Maximilian Denninger. Dlr-rm/blenderproc. `https://github.com/DLR-RM/BlenderProc`.

[3] Yarin Gal and Zoubin Ghahramani. Dropout as a bayesian approximation: Representing model uncertainty in deep learning. In *international conference on machine learning*, pages 1050–1059. PMLR, 2016.

[4] Jakob Gawlikowski, Cedrique Rovile Njieutcheu Tassi, Mohsin Ali, Jongseok Lee, Matthias Humt, Jianxiang Feng, Anna Kruspe, Rudolph Triebel, Peter Jung, Ribana Roscher, et al. A survey of uncertainty in deep neural networks. *arXiv preprint arXiv:2107.03342*, 2021.

[5] Balaji Lakshminarayanan, Alexander Pritzel, and Charles Blundell. Simple and scalable predictive uncertainty estimation using deep ensembles. *Advances in neural information processing systems*, 30, 2017.

[6] Murat Sensoy, Lance Kaplan, and Melih Kandemir. Evidential deep learning to quantify classification uncertainty. *Advances in Neural Information Processing Systems*, 31, 2018.

[7] Connor Shorten and Taghi M Khoshgoftaar. A survey on image data augmentation for deep learning. *Journal of big data*, 6(1):1–48, 2019.