IN ThoughtBridge Winter Program
Deep Learning for Computer Vision
Problem Set 1: Segmentation and Uncertainty

This Problem Set will cover segmentation in computer vision as well as uncertainty in deep learning. First, you will answer short-answer exercises, and then move forward to the software lab component of the Problem Set. **Problem Set 1 is designed to be completed in groups of 1-4 people**. Please implement your software lab in Python using TensorFlow or Pytorch. Please review the lecture materials on segmentation and uncertainty estimation in advance of this Problem Set. **Please save your code and results for submission.**

Exercises (20 points)

1. What is the loss function for a deterministic segmentation model? What is the connection to standard image classification? (5 points)
2. What is the difference between aleatoric and epistemic uncertainty in deep learning? (5 points)
3. To capture epistemic uncertainty, we can model the segmentation network using principles of Bayesian deep learning, where a probability distribution is maintained over each of the individual network weights. Dropout provides a way to approximate such a Bayesian neural network. (10 points)
    a. How does sampling in the Dropout model during test time allow for epistemic uncertainty estimation? Provide a brief explanation and any equations, if applicable.

Software Lab (80 points)

In this portion of the Problem Set, you will implement a network for semantic segmentation in image data, and also generate estimates of aleatoric and epistemic uncertainties associated with the segmentation. You are flexible in the model and architecture you choose. Your solution should follow this general template and provide the relevant deliverables:

1. Download the data. It is provided in **lab2_train_data.h5 and lab2_test_data.h5**. The data are stored in h5 py format and contain the following fields:
    a. `rgb:` (NxHxWx3) collection of color images
    b. `seg:` (NxHxWx1) collection of segmentation maps with classes labelled by index (the index ranges from 0 to K-1)
    c. `color_codes:` (Kx3) list of RGB colors for labelling every segmentation class
    Implement a data loader class to handle the downloaded data. For more information on the dataset please refer to: CityScapes dataset. (5 points)
2. Define the model. **Provide a schematic of your architecture depicting its overall structure and the relevant parameters.** (20 points)
3. Define the loss function and optimizer. (10 points)

4. Train the network. (5 points)
5. Test the resulting network on examples from an independent test set. Implement and present in a single PDF slideshow the following: (40 points)
    a. Predictions for (μ, *aleatoric*, *epistemic*) **on 5 different input examples**.
    b. Visualizations for (μ, *aleatoric*, *epistemic*) **on 5 different input examples.**
    c. **Comment briefly on how the model's performance could be improved.**
    d. **Please save your code and results for submission.**