CMPSC 497 - Homework 2: Vanishing Gradients and Feature Visualization

Due: Feb 7, 2024 @ 11:59 pm EST

1 Introduction

Homework 2 consists of two sections, the vanishing gradients and feature visualization. In this assignment, we will first look at how activation functions affect vanishing gradients. Then, we create/train/test a neural network on a standard image classification benchmark and visualize features from the network. We allow for the homework to be completed locally (with Jupyter) or through Google Colab, though we recommend Colab as it provides GPU, which speeds up the training significantly.

2 Setup

Although this assignment will not need a GPU to complete, we do recommend completing the assignment in Google Colab, so you can familiarize yourself with the platform for future assignments. If you want to complete the assignments in Colab, visit the Colab website (`https://colab.research.google.com/`) and upload the assignment notebook (.ipynb). To use a GPU, set your runtime to include a hardware accelerator first. We suggest looking at the included software setup document (software_setup.pdf in the first homework zip file) as a general guide for working with Colab and Jupyter.

The following are the steps to get the code and data ready in Google Colab. Go to Google Colab's website → "Upload" → upload one of the .ipynb files → complete the coding exercises in the cells. This can be done by clicking the file icon on the left side of colab, and then clicking the upload icon below "Files".

3 Assignment Details

You are expected to implement two files in two sections:

- Activation Functions and Vanishing Gradients
  `1_activation_function_and_vanishing_gradient.ipynb`
- Image Classification and Feature Visualization
  `2_image_classification_and_feature_visualization.ipynb`

3.1 Activation Functions and Vanishing Gradients

This exercise will explore how different activation functions (sigmoid, ReLU) impact the gradient descent optimization in a three-layer fully connected neural network. We will also get to see vanishing gradients caused by chain rule, a problematic property of deep neural networks. The sigmoid function "squashes" inputs to lie between 0 and 1. Unfortunately, this means that for inputs with sigmoid output close to 0 or 1, the gradients with respect to those inputs are close to zero. This leads to the phenomenon of vanishing gradients, where gradients drop close to zero, and the net does not learn well. On the other hand, the ReLU function (max(0, x)) does not saturate with input size.

3.1.1 Image Classification and Feature Visualization

This notebook covers training a classifier, Convolutional Neural Network (CNN) in this case, on an image classification benchmark. It will also demonstrate how users can interact with their network and visualize certain properties of it.

4 Submission

To submit the assignment, you only need to upload the completed two files:

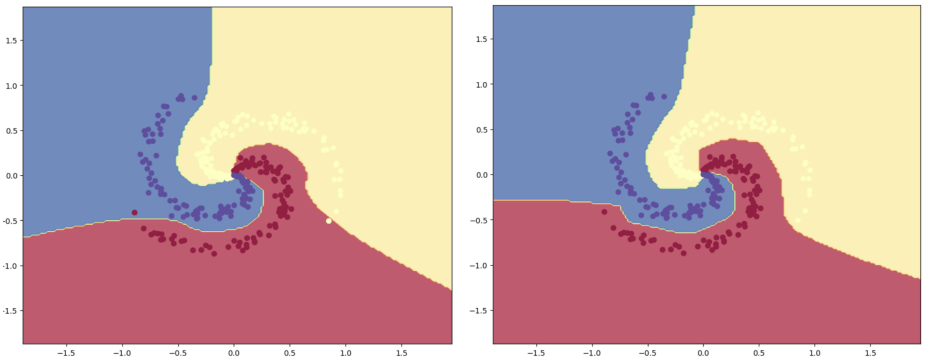
- `1_activation_function_and_vanishing_gradient.ipynb`
- `2_image_classification_and_feature_visualization.ipynb`

You do not need to include any other files (e.g., checkpoints, images, or h5py).

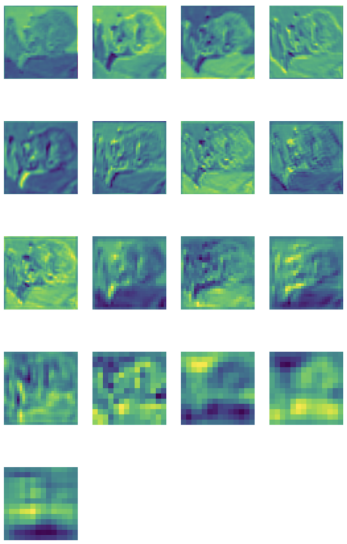
5 Expected Output

Students can follow the instructions in notebook files (.ipynb). The expected outputs, e.g., accuracy and plot, are listed in notebooks.

In section 1 - Activation Functions and Vanishing Gradients, the expected classifier boundary figures for using sigmoid and ReLU activation functions, are shown below.



In section 2 - Image Classification and Feature Visualization, the expected feature visualization figures for each layer of fine-tuned ResNet-18, are shown below.



6 Rubric

This assignment is worth 10 points, with the following breakdown. (Note: Each cell block may consist of several questions. A cell block is correct only if all the questions in the cell block are correct.)

Activation Functions and Vanishing Gradients:

Section	**Score** (total: 4 points)
Activation Functions (sigmoid, ReLU)	1 point
Forward Pass	1 point
Backward Pass Using Gradient Descent	2 points

Image Classification and Feature Visualization:

Section	**Score** (total: 6 points)
Data Transformation	0.5 point
Loss Function (Cross-Entropy Loss)	0.5 point
Optimizers (Adam and SGD)	1 point
Initialize from Pretrained Weights (ResNet-18)	2 points
Feature Visualization	2 points