Project IV: Generative Neural Networks

1 Introduction

In this project, you will implement a generative neural network, more precisely a VariationalAutoencoder (VAE).

2 Mandatory Part

Implement a Variational Autoencoder (VAE) to generate images of digits between 0 and 9. For inspiration for network architectures, please have a look at this paper (in particular, Section 3and Appendices B and C.2) and this tutorial. Also experiment with variations of this architecture to see whether you can find a network that performs better. For simplicity, use a 2D latent space.For training and testing, use the MNIST dataset. You can find instructions on how to use the MNIST dataset inside MATLAB here.

What to include in the report.Your report should consist of the following:

- A short abstract describing the problem behind the project and outlining your solution.
- A "Method" section describing your approach: Explain how VAEs work in your own words and present and discuss the cost function that is optimized. Make sure to explain all variables that you use. You do not need to derive the cost function. Also discuss the network architectures that you use for experiments. This section should be about one page long.
- A "Experimental Evaluation" section describing the experiments you perform with yourapproach as well as the results of these experiments:
  - Describe the parameters you used for training, e.g., the learning rate, whether youused momentum, etc., as well as the number of epochs that you train your networks.
  - Show example images generated by the network architectures that you tried. Discussthe results, i.e., point out which network performs best and point out failure cases.

3 Theoretical part

Answer the following questions in your report. Make sure to use your own words and justify your answers.

(a) The ELBO.In your own words, explain why we optimize the Empirical Lower BOund(ELBO) rather than log(p(x)) when training a VAE.

(b) VAE-GANs.In the lecture, we used the tendency of VAEs to generate blurry images to introduce Generative Adversarial Networks (GANs) as a way of learning a better loss function for the reconstructed images. In your own words, explain how the discriminator part of a GANcan be integrated into a VAE.

(c) Task driven losses.In some cases, VAEs or GANs are used to create additional training data. For example, in the advanced part below, we will use the VAE to generate training data for a digit classification problem. Following this example, can you think of a way of using a classifier as part of the loss when training the VAE? Explain your solution and the motivation behind your solution.

4 Advanced Part

In this part, you will experiment with your VAE in the context of creating training data. To thisend, create a classification network for the digits 0 to 9 and train it on the training set of theMNIST dataset. Your network should be able to achieve a test accuracy of at least 90% on thetest set. Since MNIST is a relatively easy dataset, your network does not need to be too deep(two convolutional layers (with a max-pooling layer in between) followed by two fully connectedlayers should be sufficient).Next, perform the following experiment: Use half of the MNIST training set to train your VAE.For the other half, use 20%, 50%, 100% of its images, together with an equal amount of imagesgenerated by your VAE, to train your classifier.

What to include in the report.Extend your report to include the following:•Extend the "Experimental Evaluation" section:
Report the accuracy of the classifier trainedwith 20%, 50%, 100% of the images in the other half of the training set on the MNIST testset. How does the accuracy change when also training on synthetic images?