

# Project description and feedback

July 21, 2024

## 1 Project Description

In this project, you will estimate geometries using variational autoencoders (VAEs) on a subset of (non-binarized) MNIST. The project is divided into three parts:

### 1.1 Formalities

Hand in a single report in PDF format and your code in a single file (zip or tar archive). The report must include:

- A single page with the main text, including figures and tables. Include names, student numbers, course number, and the title "Mini-project 2".
- Unlimited pages of references.
- A single page of well-formatted code snippets.

Use at least font size 10pt and margins of at least 2cm. Content violating these limitations will not be evaluated.

### 1.2 Part A: Fisher-Rao Geodesics

Train a VAE with a standard Gaussian prior and a product of either continuous Bernoulli or Bernoulli likelihood,  $p(x|z)$ , on a subset of MNIST with 3 classes and 2048 observations. The latent space should be two-dimensional for easier plotting.

Implement an algorithm to compute geodesics under the Fisher-Rao metric. Include in the report:

- A plot of latent variables with geodesics between at least 50 random pairs.
- Code snippets for computing the Fisher-Rao energy of a curve and geodesics.
- Discussion of the qualitative behavior of the geodesics.

### 1.3 Part B: Ensemble VAE Geometry

Train a VAE with an ensemble decoder of 10 members. Implement an algorithm to compute the model-average Fisher-Rao curve energy and minimize it to compute geodesics. Approximate the model-average Fisher-Rao curve energy as follows:

$$E(c) \approx \sum_{i=0}^N \text{KL}(f_l(c(t_i)) \| f_k(c(t_{i+1})))$$

where  $f_l$  and  $f_k$  are ensemble decoder members drawn uniformly.

Include in the report:

- A plot of latent variables with geodesics using the ensemble decoder VAE.
- A plot of average proximity between geodesics and latent variables as a function of ensemble members (1 to 10).
- Relevant code snippets.

### 1.4 Part C: Impact of Initialization (Optional)

If time allows, initialize geodesic curves by computing geodesics under an abstract density metric. Discuss the impact of the initialization strategy and include relevant code snippets.

## 2 Feedback

Part A: Great discussion and analysis

Part B: Again, great discussion

Part C: Citation for the abstract density metric is wrong, but besides this insignificant point: great job