ONLY GOD

1402-2023

mansoori@shirazu.ac.ir

Neural Network & Deep Learning

Deep AE

CSE & IT Department
School of ECE
Shiraz University

AutoEncoder

(AE)

mansoori@shirazu.ac.ir

AE

mansoori@shirazu.ac.ir

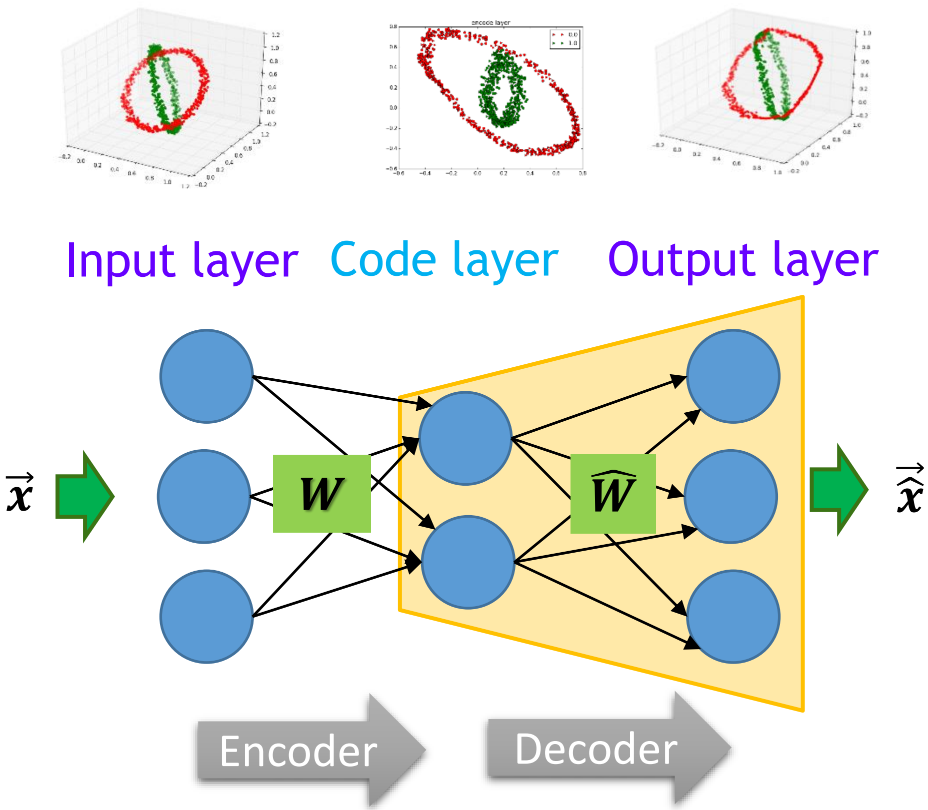
- A neural network trained to attempt to copy its input to its output
- Typically used in dimensionality reduction
  - Works only if the inputs are correlated
- Used for image denoising wherein a clear noise-free image could be generated using a noisy one
- Recently, widely used for learning generative models
- By adding regularization, it will be able to play with the architecture instead of only the depth

mansoori@shirazu.ac.ir

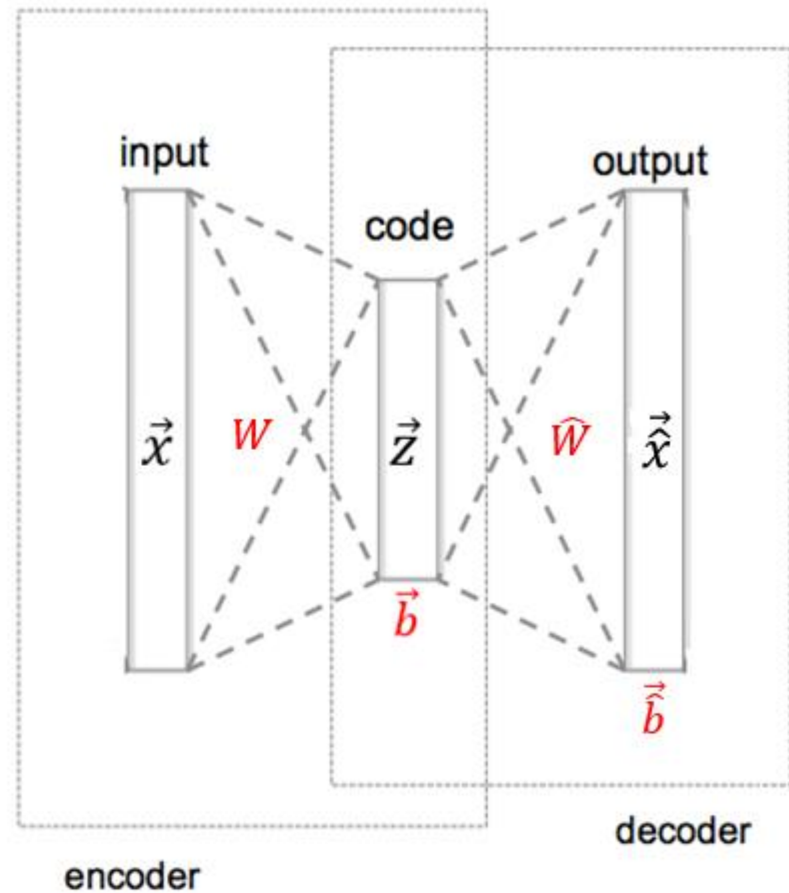
AE Usage

- Compression
  - Not popular as compression algorithms still perform better
- Denoising
  - Using noisy images as input of AE while trying to minimize difference between reconstructed output and original clean image
- Dimensionality reduction
  - Using output layer of Encoder with fewer dimensions than input to represent data in lower dimensions non-linearly
  - In contrast to PCA which does linearly
- Generating new data via generative models

Shallow AE



Input layer
Code layer
Output layer
$\vec{x}$
W
$\widehat{W}$
$\hat{\vec{x}}$
Encoder
Decoder

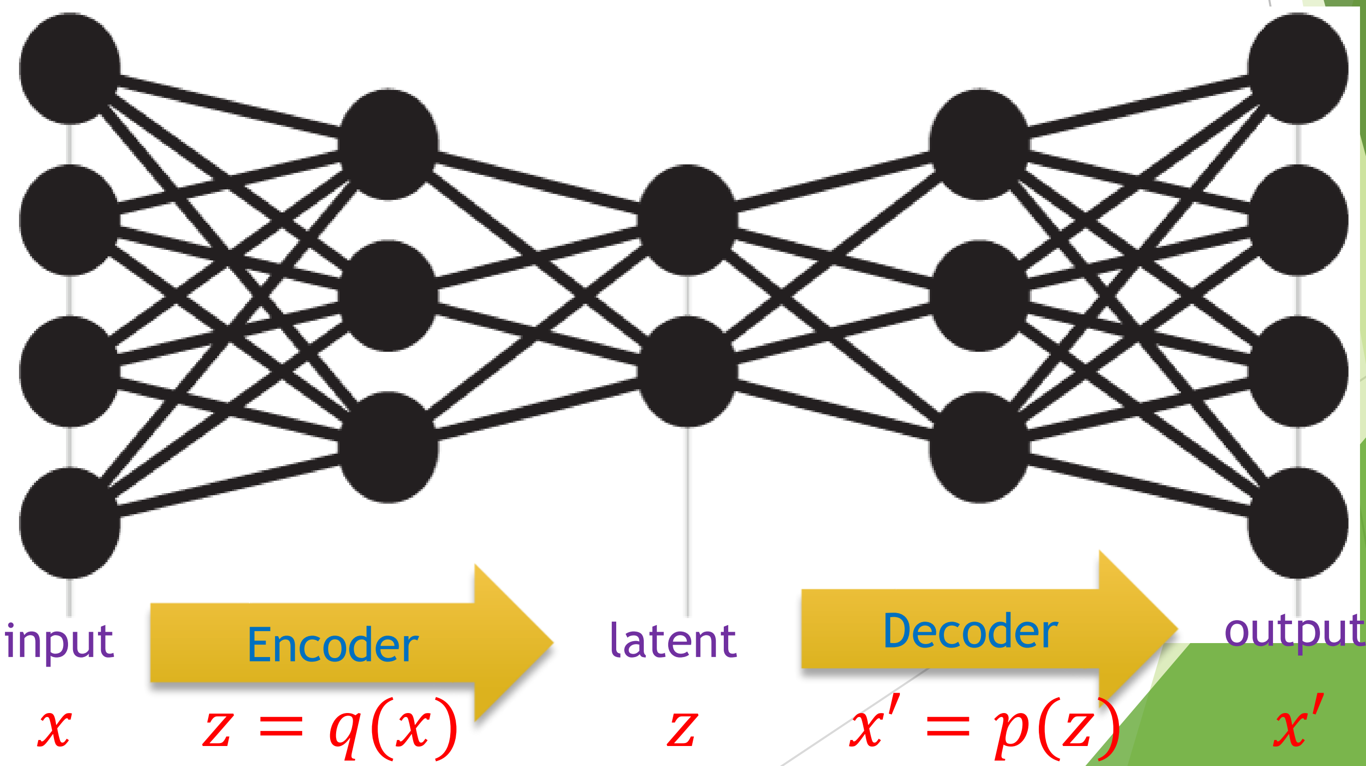


input
code
output
$\vec{x}$
W
$\vec{z}$
$\widehat{W}$
$\hat{\vec{x}}$
$\vec{b}$
$\vec{b}$
encoder
decoder

Deep MLP-AE

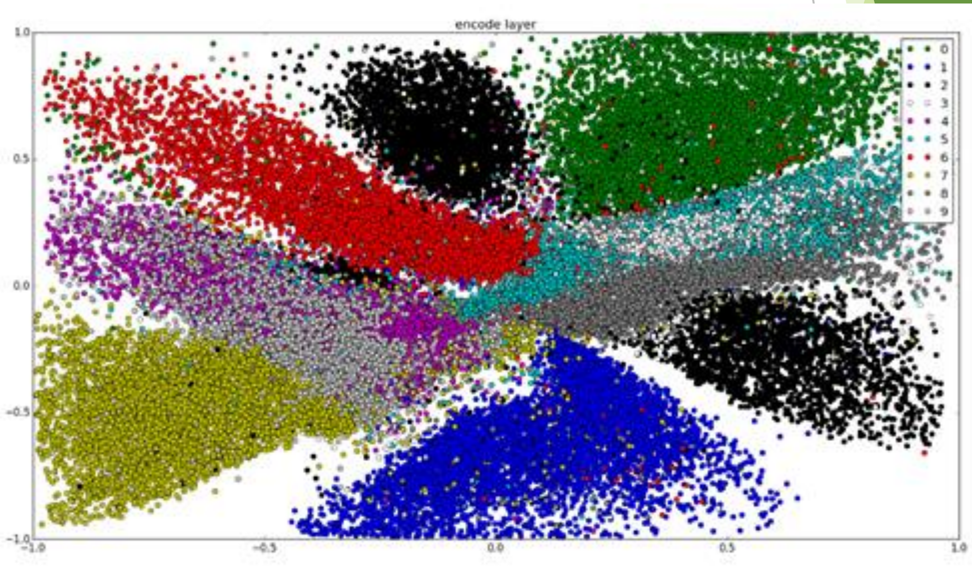
mansoori@shirazu.ac.ir

- AE: a neural network trained to attempt to copy its input to its output
- Deep MLP-AE has several hidden layers in its encoder and decoder



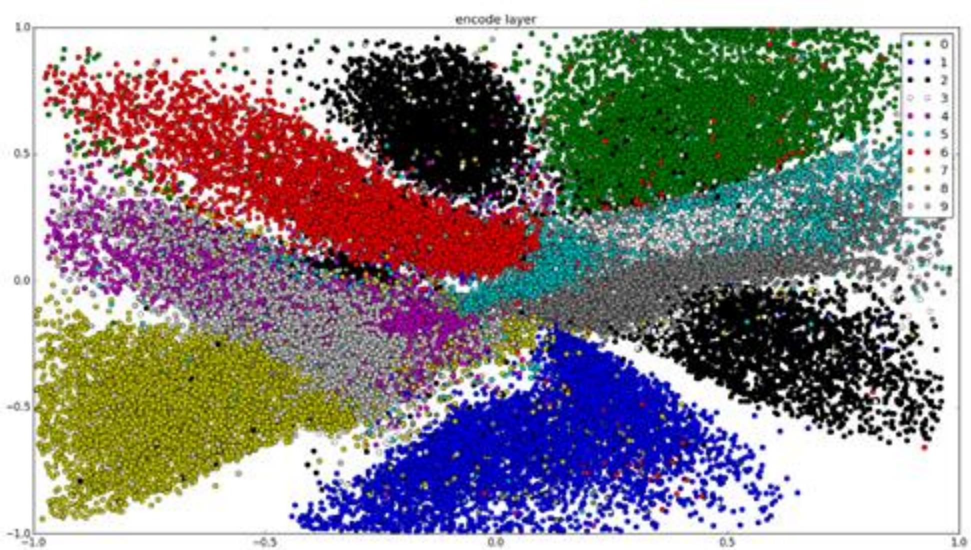
Deep AE Properties

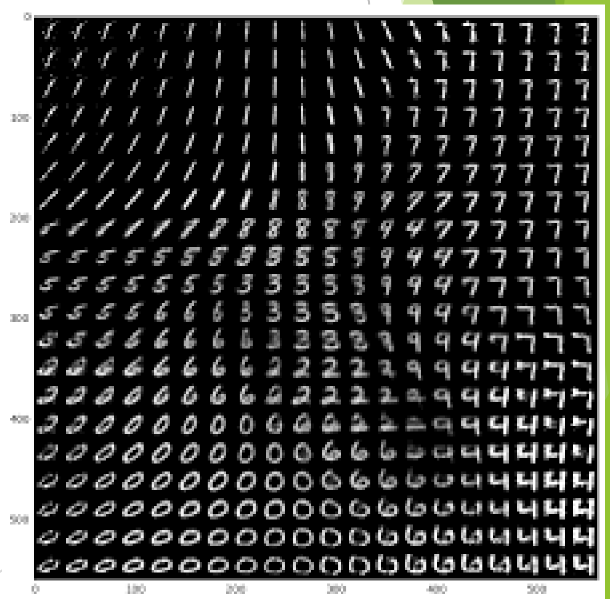
- AE can find an abstract representation of data in its encode layer which contains most information of original representation of data in a lower dimension
- Results on MNIST dataset



Deep AE Properties

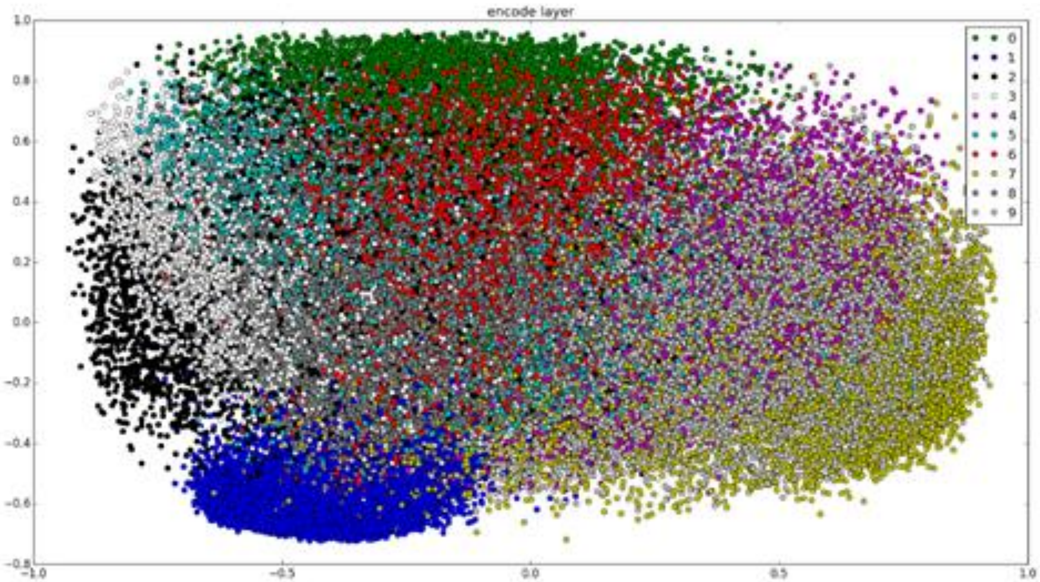
- AE is a generative model
- By generating random samples in encode layer of a trained AE, its decoder can map them to new data samples in original data space





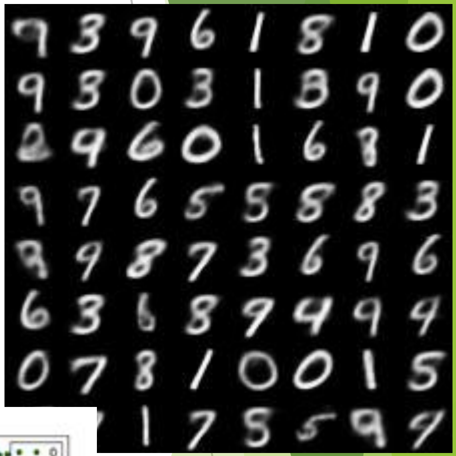
Shallow AE

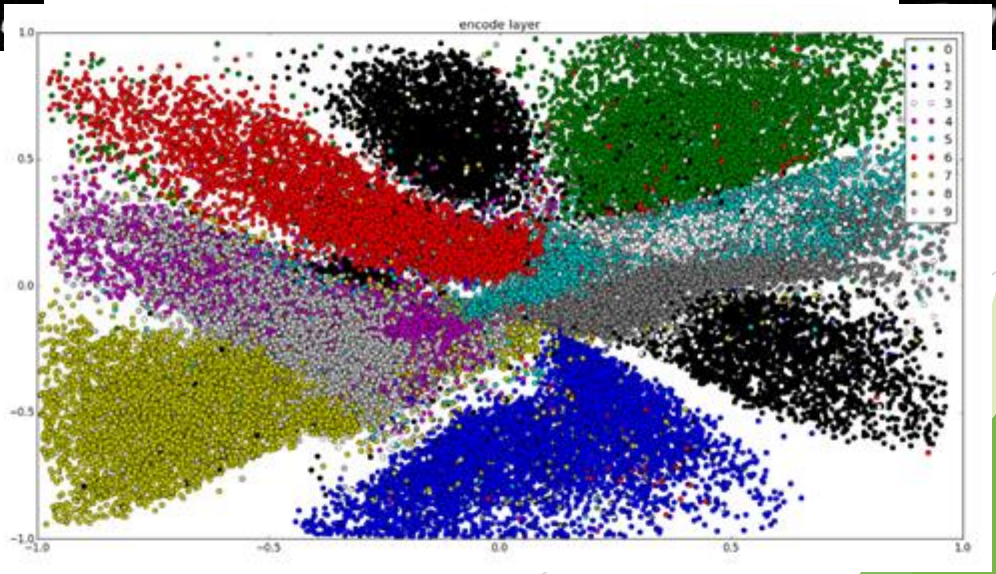
784 ⟶ 2 ⟶ 784



Deep AE

784 -> 512 -> 256 -> 128 -> 32 -> 2 -> 32 -> 128 -> 256 -> 512 -> 784

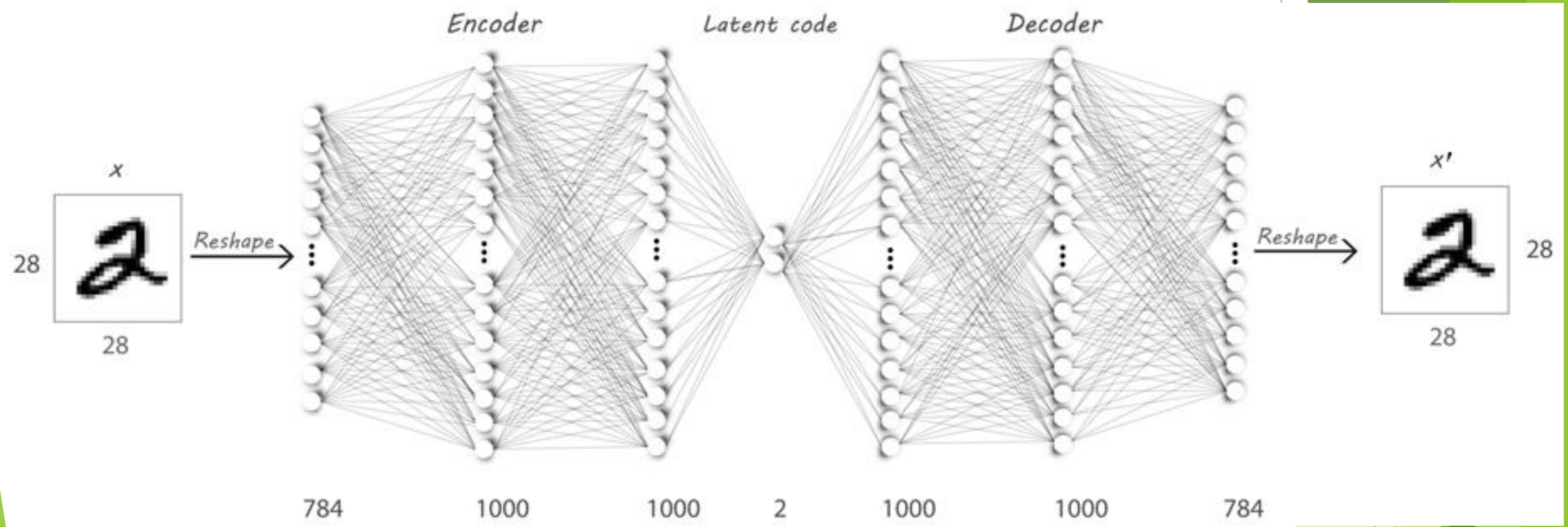




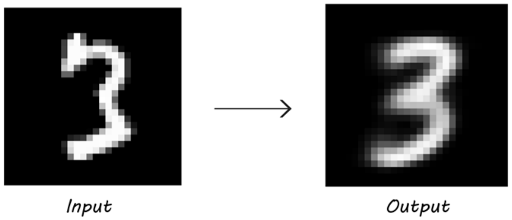
AE for MNIST Dataset

mansoori@shirazu.ac.ir

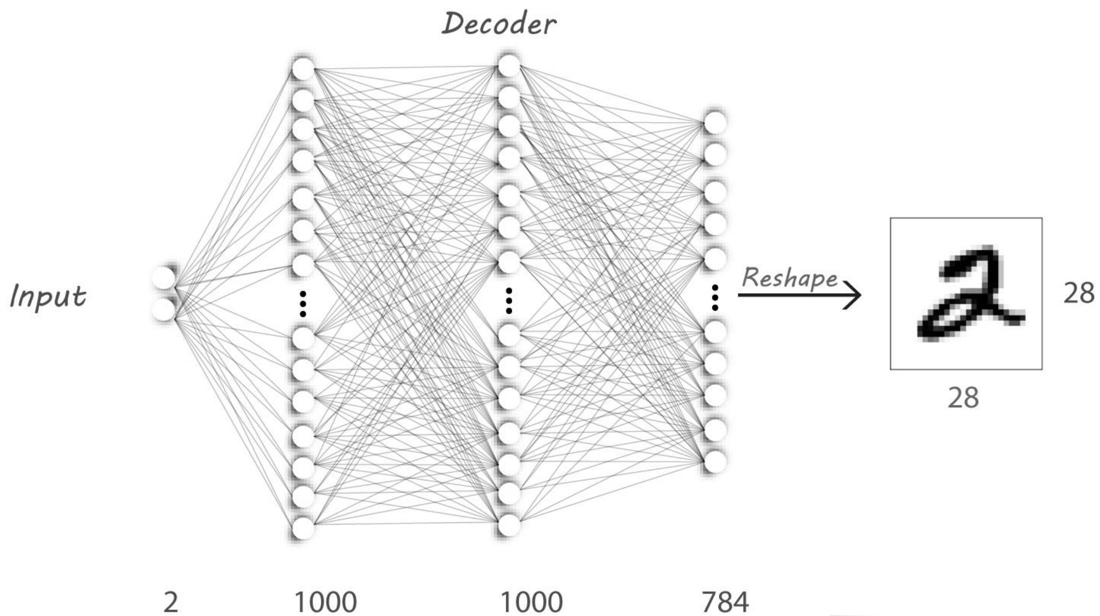
Training phase

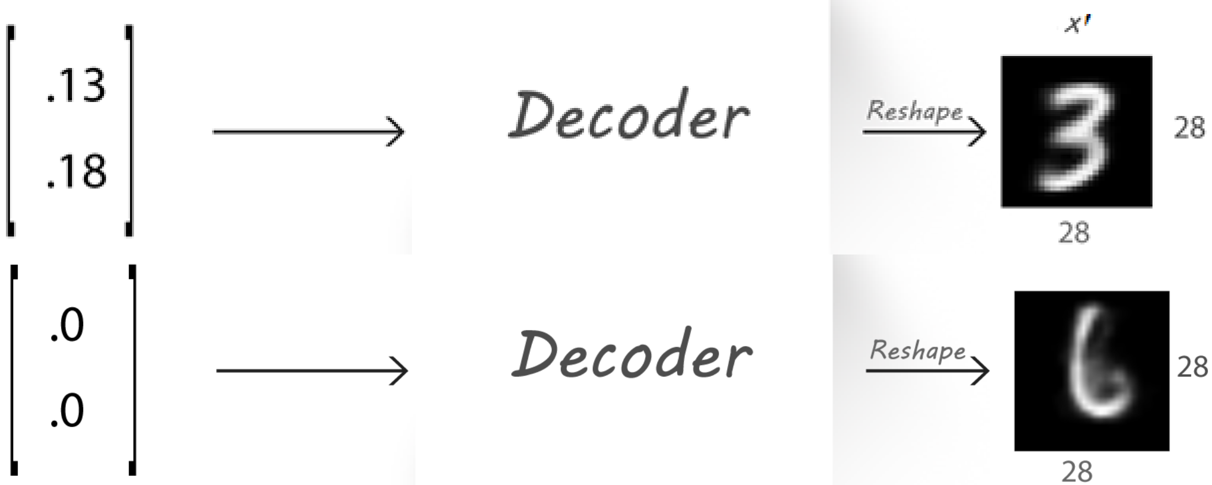


Test phase



Decoder of AE as Generator





Blurry image ---> encoder output (latent code) not follow any distribution

mansoori@shirazu.ac.ir

Variational AutoEncoder

(VAE)

Why Variational?

mansoori@shirazu.ac.ir

- In AE,
  - latent vectors, generated by encoder, tends to be irregular, unorganized, or uninterpretable

  as

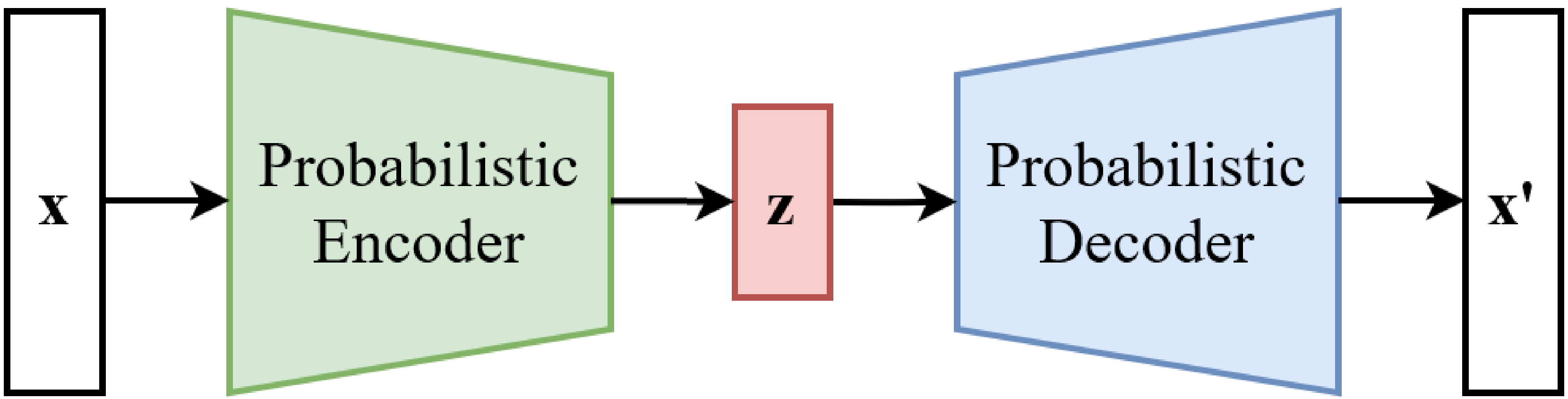
  - it only aims to reconstruct input as similar as possible without any constraint on latent space

- We would like latent space to be continuous but separated which allow interpolation between different attributes

VAE: Deep Learning + Bayesian Inference

mansoori@shirazu.ac.ir

- Combines techniques from deep learning and Bayesian variational inference
- Provides a probabilistic manner for describing an observation in latent space

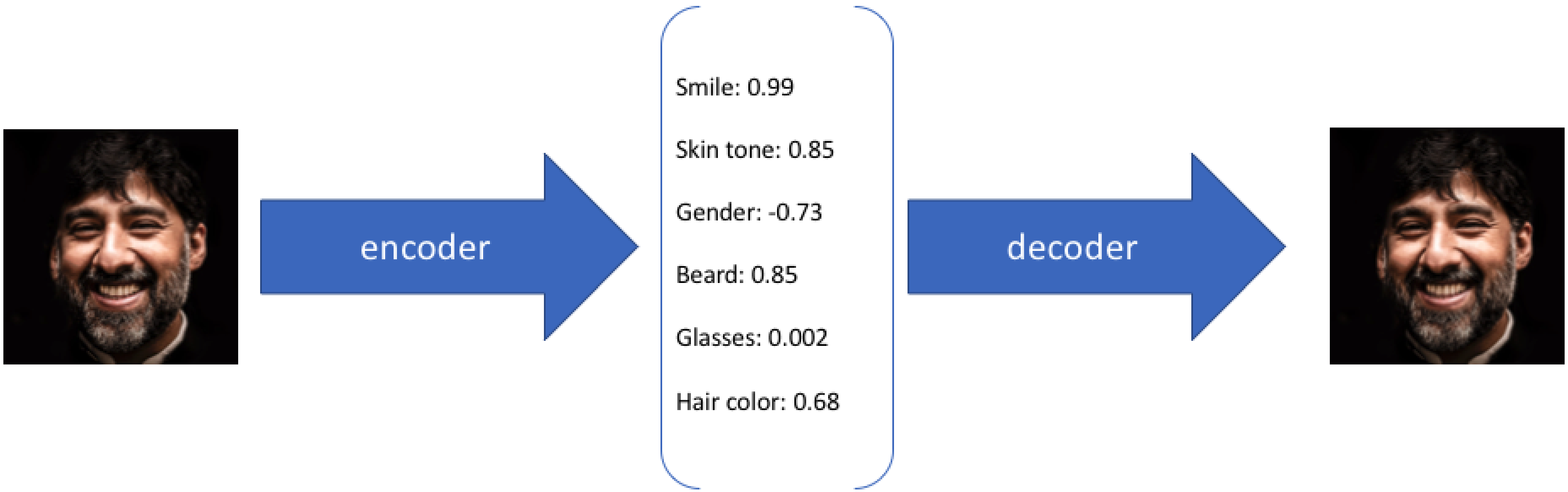


- Its encoder describes a probability distribution (instead of producing a single value) for each latent attribute

VAE Motivation

mansoori@shirazu.ac.ir

- Describing input image in terms of its latent attributes using a single value to describe each attribute



Latent attributes

- Preferring to represent latent attributes as range of possible values

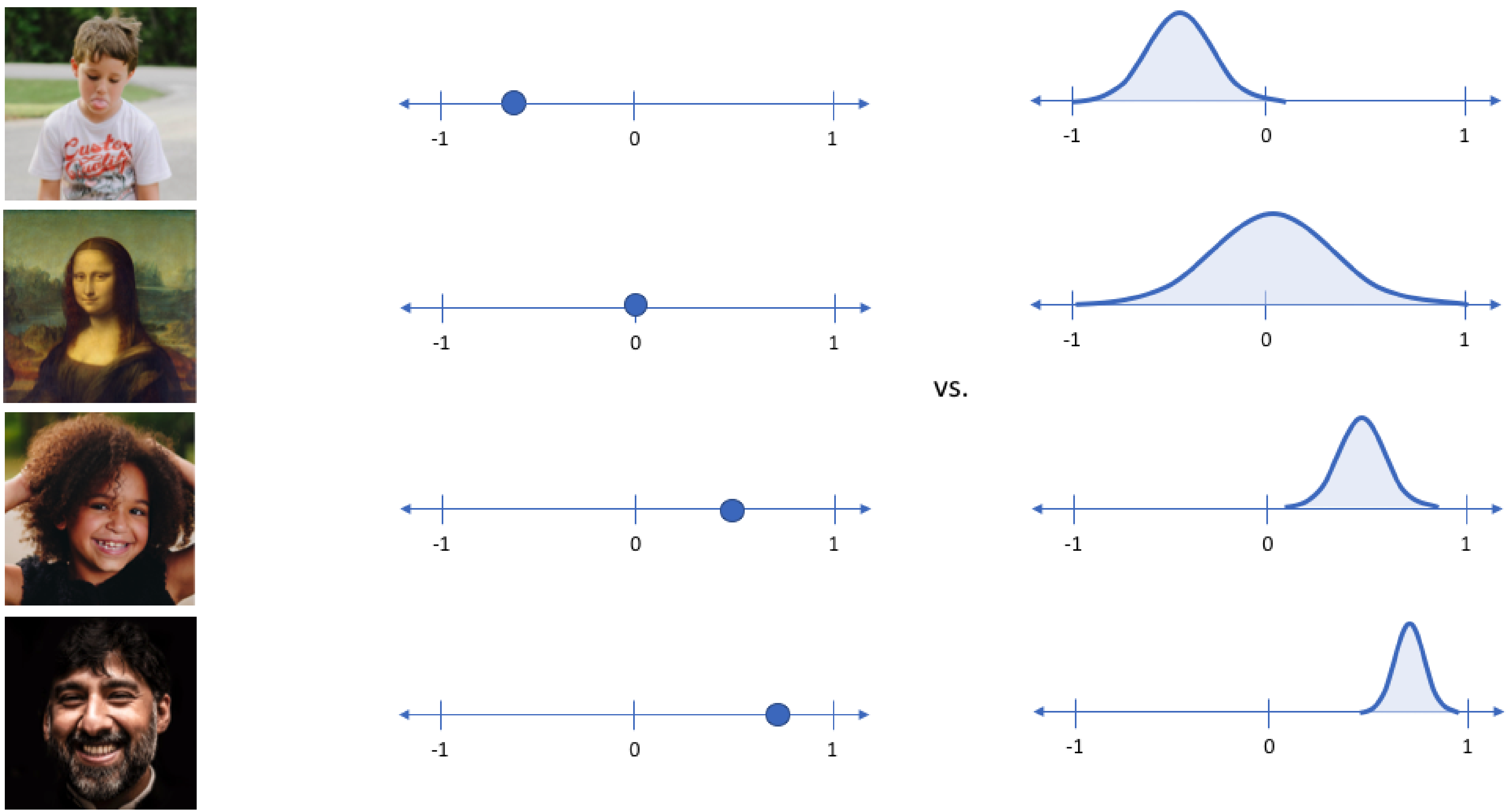
VAE Motivation

mansoori@shirazu.ac.ir

Representing latent attributes as a probability distribution

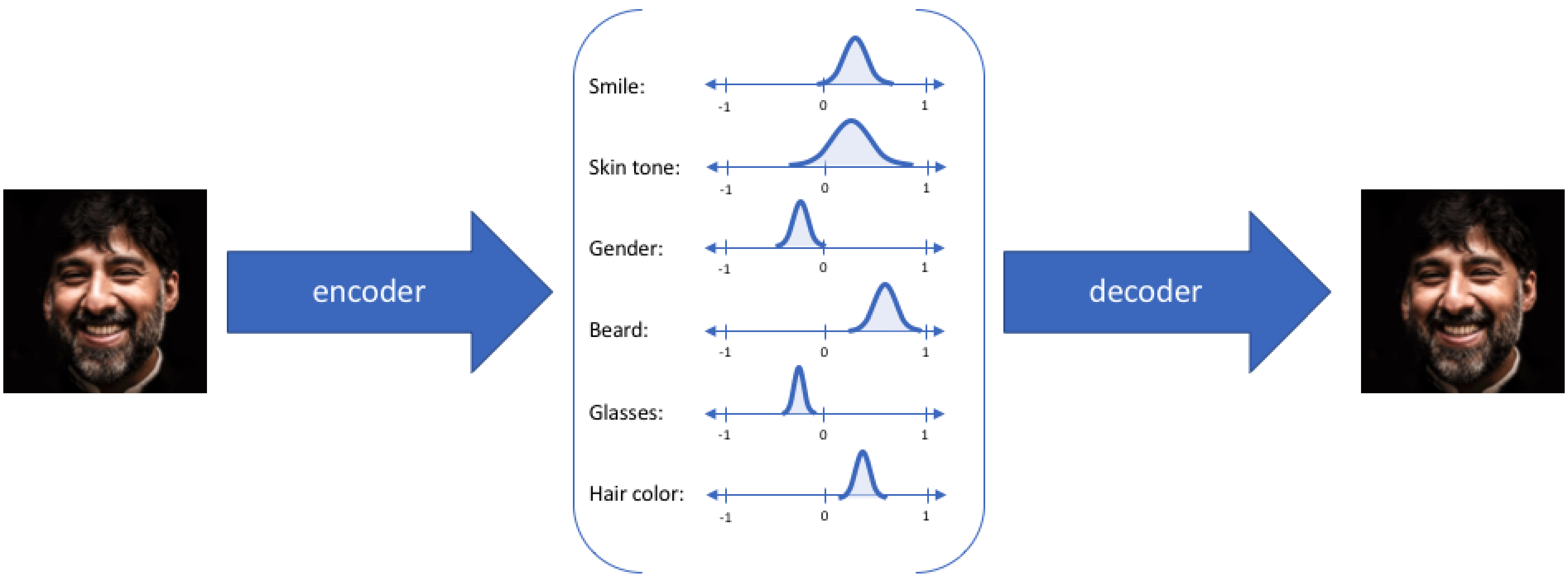
Smile (discrete value)

Smile (probability distribution)



VAE Motivation

Describing input image in terms of its latent attributes using a probability distribution to describe each attribute

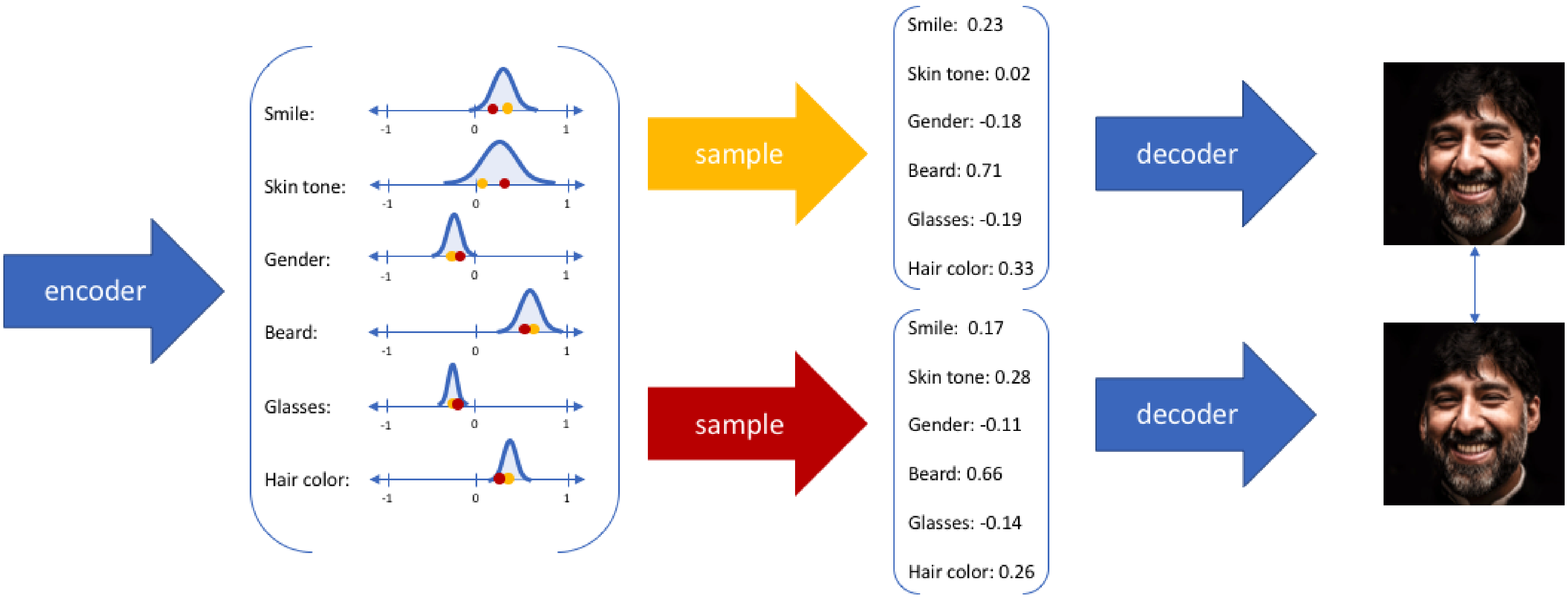


Latent attributes

VAE Motivation

mansoori@shirazu.ac.ir

Expecting an accurate reconstruction for any sample from the latent state distributions



Latent distributions

Sampled latent attributes

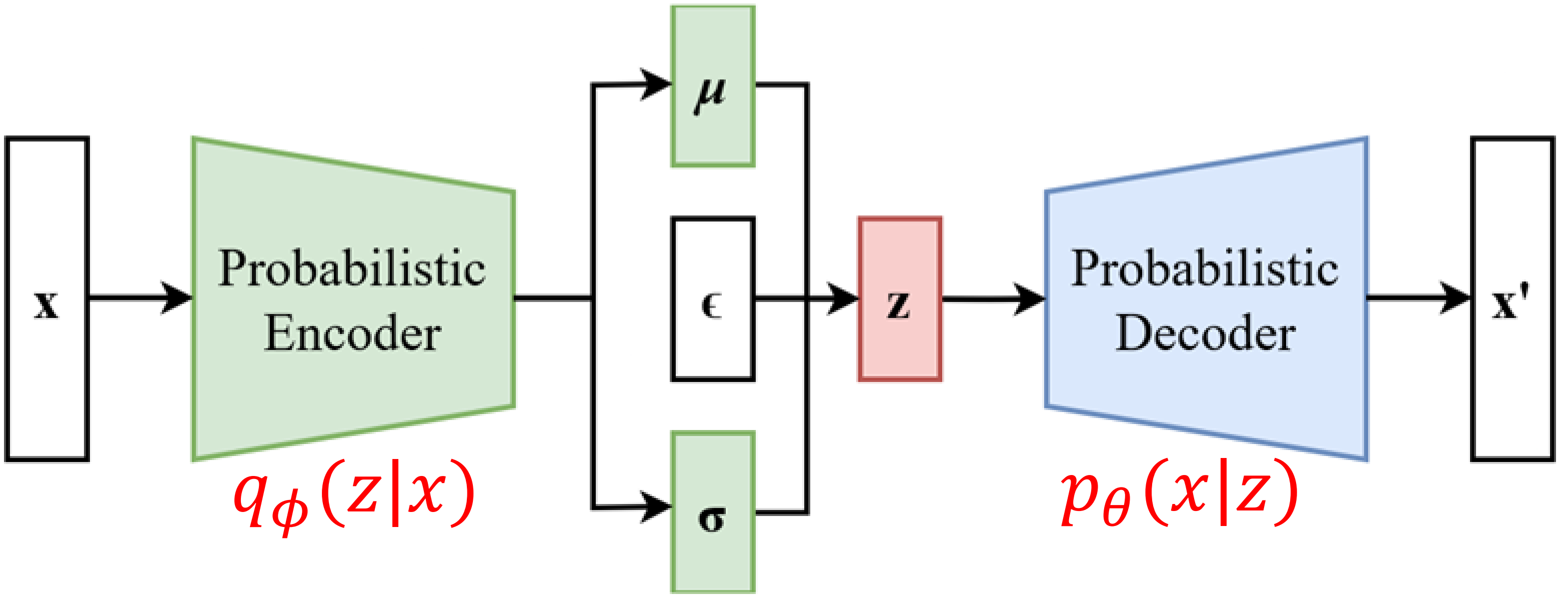
AE vs VAE

- AE is regular: each layer represents encoded data

- VAE is Bayesian: layers represent distribution of data
  - Input to Encoder:
    - Bernoulli distribution (binary data)
    - Gaussian distribution (real-valued data)
  - Latent layer: Gaussian distribution
  - Input to Decoder: samples from Gaussian distribution
  - Output of Decoder:
    - Bernoulli distribution (binary data)
    - Gaussian distribution (real-valued data)

mansoori@shirazu.ac.ir

VAE Forward Pass



- Encoder $q_\phi(z|x)$ approximates posterior distribution $p(z|x)$ $\qquad q_\phi(z|x) = \mathcal{N}(z; \mu_\phi(x), \mathrm{diag}(\sigma_\phi(x)))$
- Decoder carries conditional likelihood distribution $p_\theta(x|z)$ to approximate $p(x|z)$
- VAE computes $p(x'|x)$