California State University
Los Angeles

Machine Learning

Autoencoders, Variational Autoencoder & Conditional Variational Autoencoder

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Agenda Overview

01 Autoencoders

02 Why Use Autoencoders?

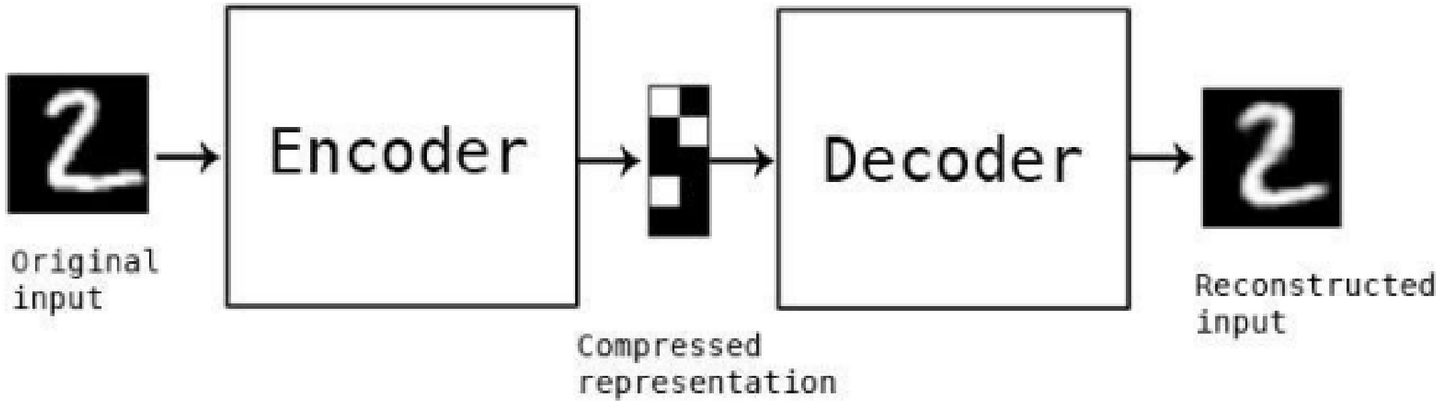
03 Variational Autoencoders (VAE)

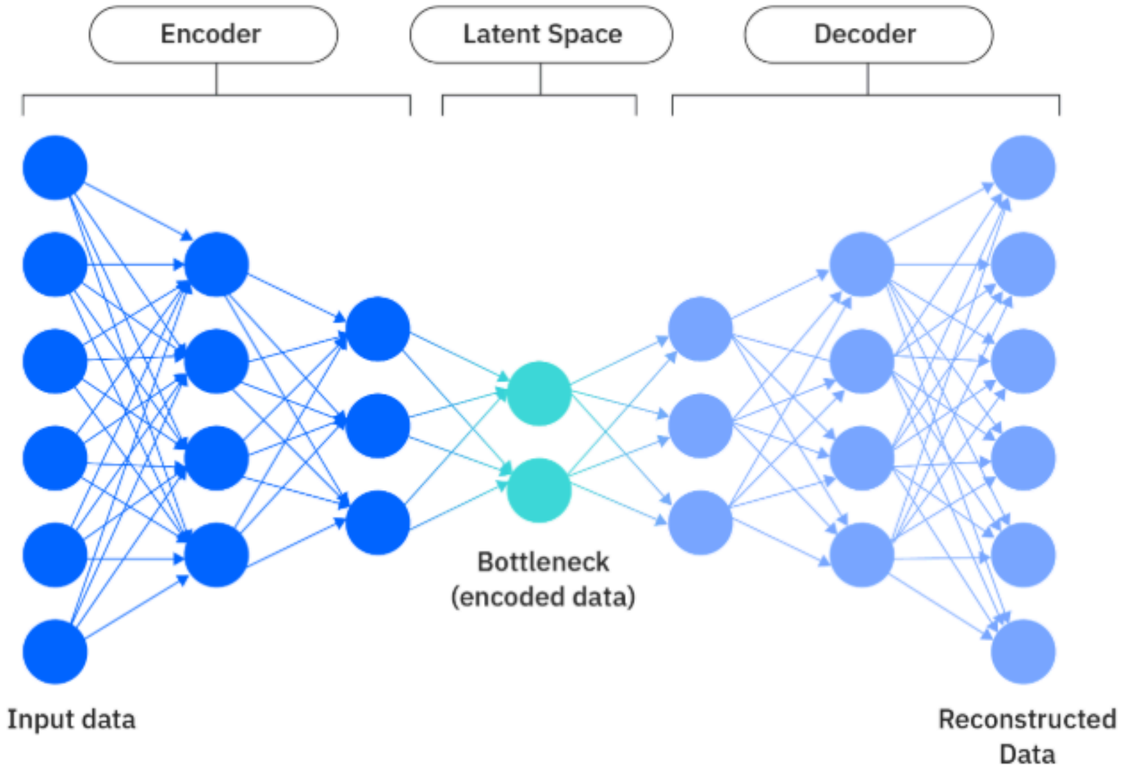
04 Conditional Variational Autoencoder (CVAE)

Autoencoders

- A type of artificial neural network used to learn efficient codings of input data.
- It is an unsupervised learning model designed to reconstruct its input.
- Composed of two main parts:
  - Encoder
  - Decorder
- The model trains by minimizing reconstruction error using loss functions like Mean Squared Error or Binary Cross-Entropy. These are applied in tasks such as noise removal, error detection and feature extraction where capturing efficient data representations is important.

Architecture of Autoencoder





- Encoder: Learns meaningful features
- Bottleneck: Forces compression
- Decoder: Learns how to reconstruct

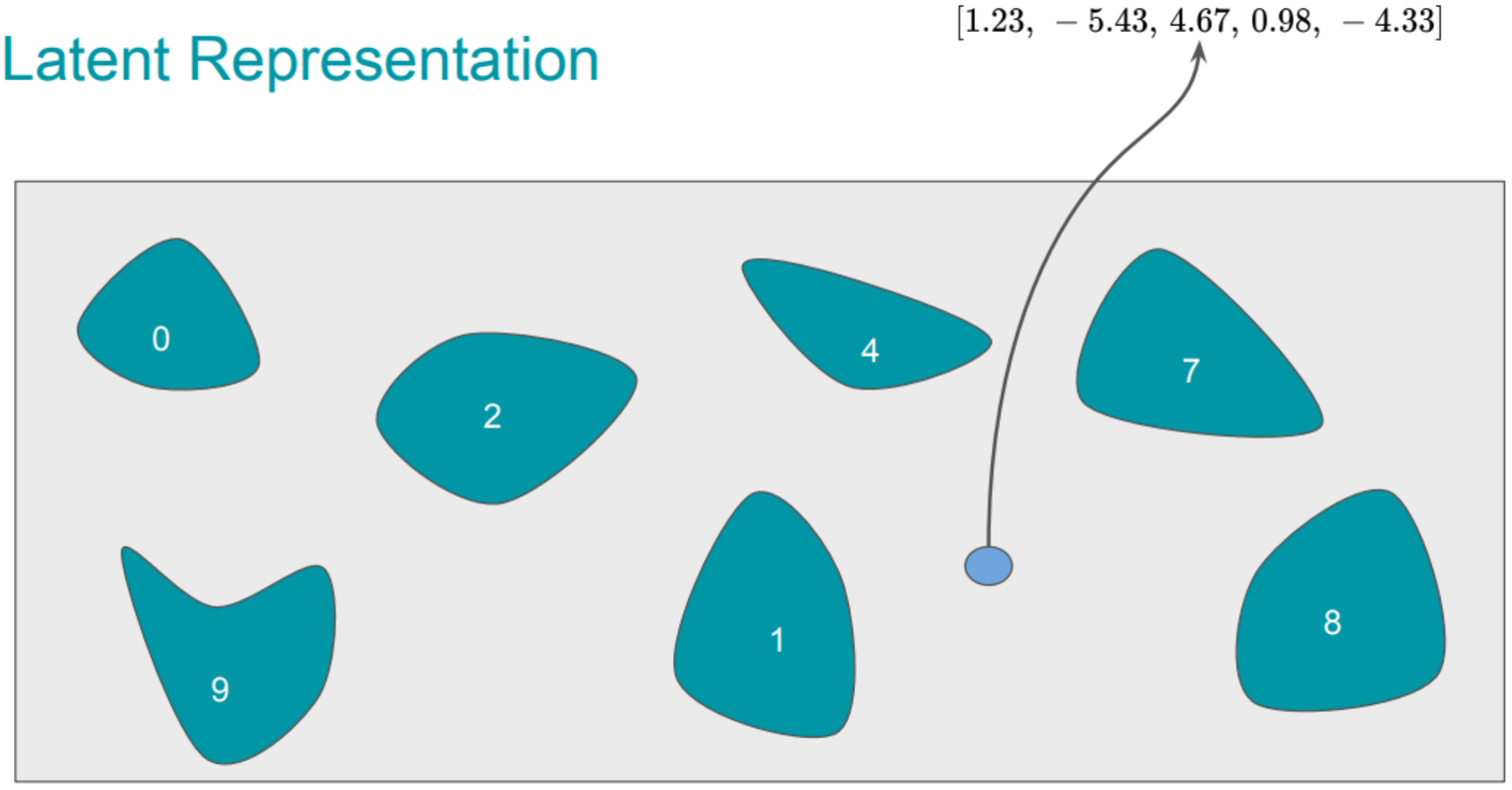
Why Use Autoencoders?

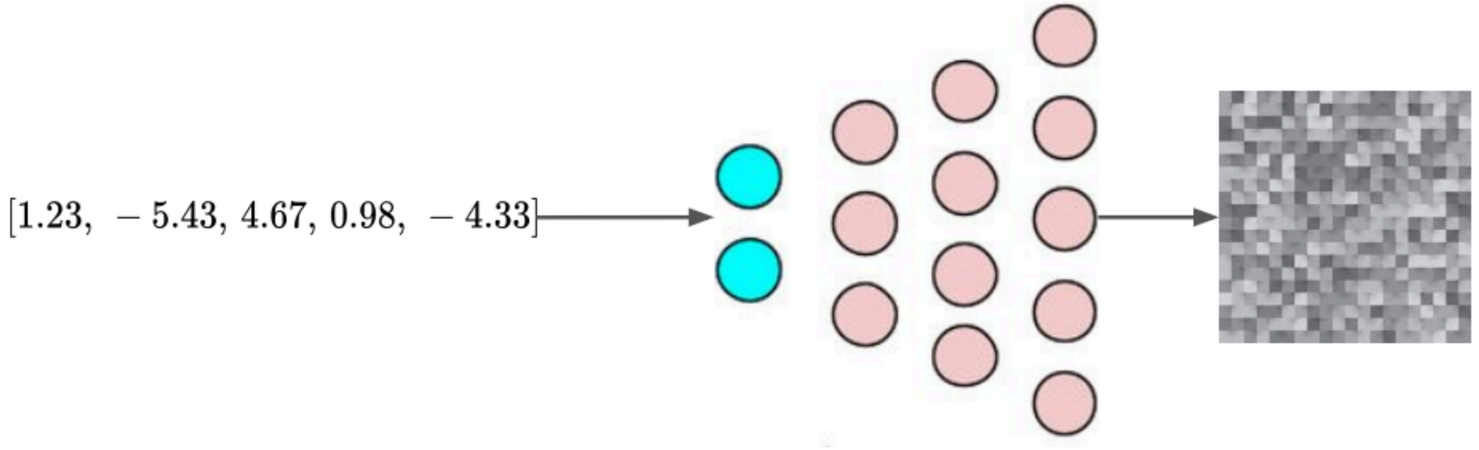
- Dimensionality reduction (like PCA, but nonlinear)
- Noise reduction and denoising
- Anomaly detection
- Pretraining deep networks

Types of Autoencoders

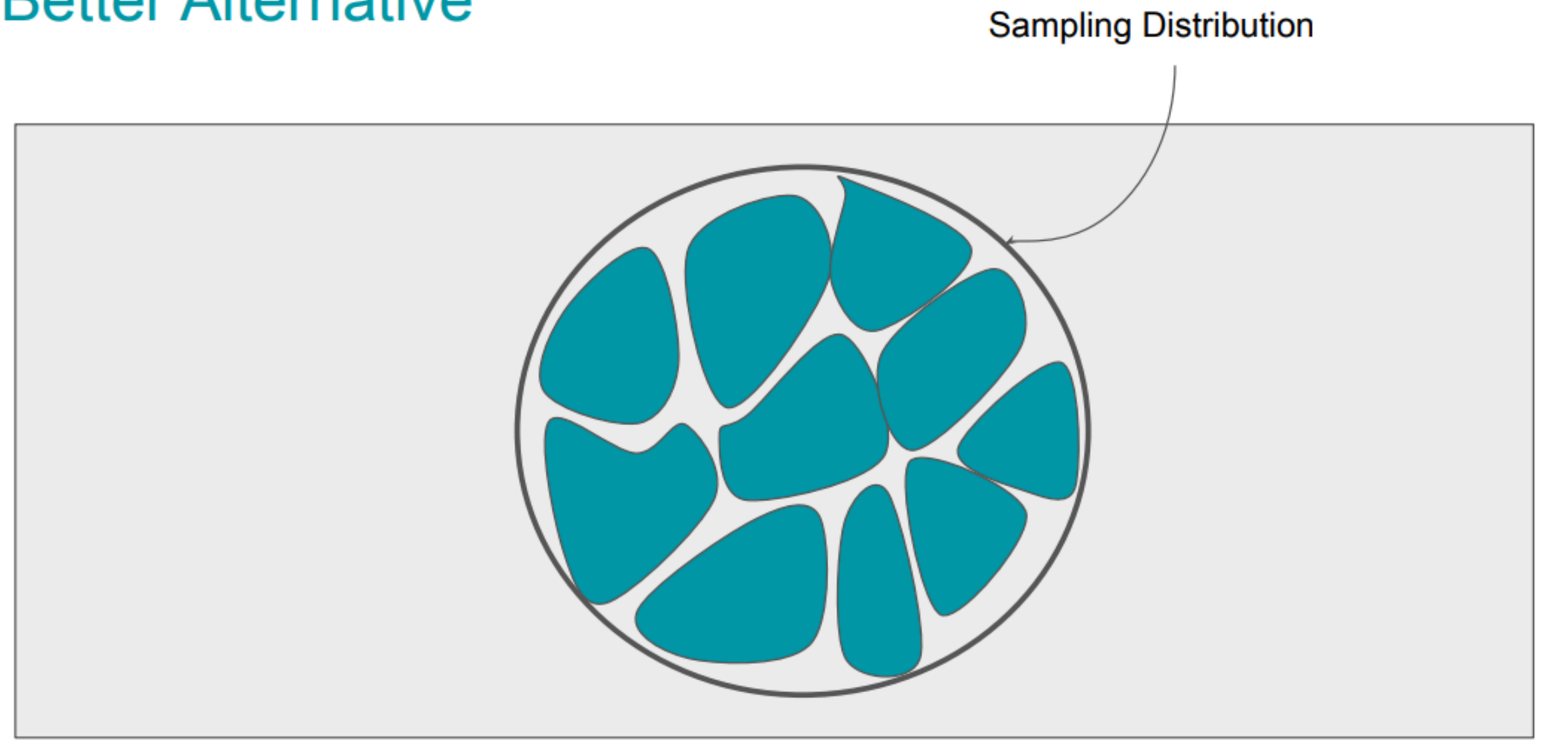
1. Denoising Autoencoder (DAE) – learns to remove noise
2. Sparse Autoencoder – adds sparsity constraint on the latent space
3. Contractive Autoencoder – adds robustness to small input changes
4. Variational Autoencoder (VAE) – probabilistic generative model

Latent Representation

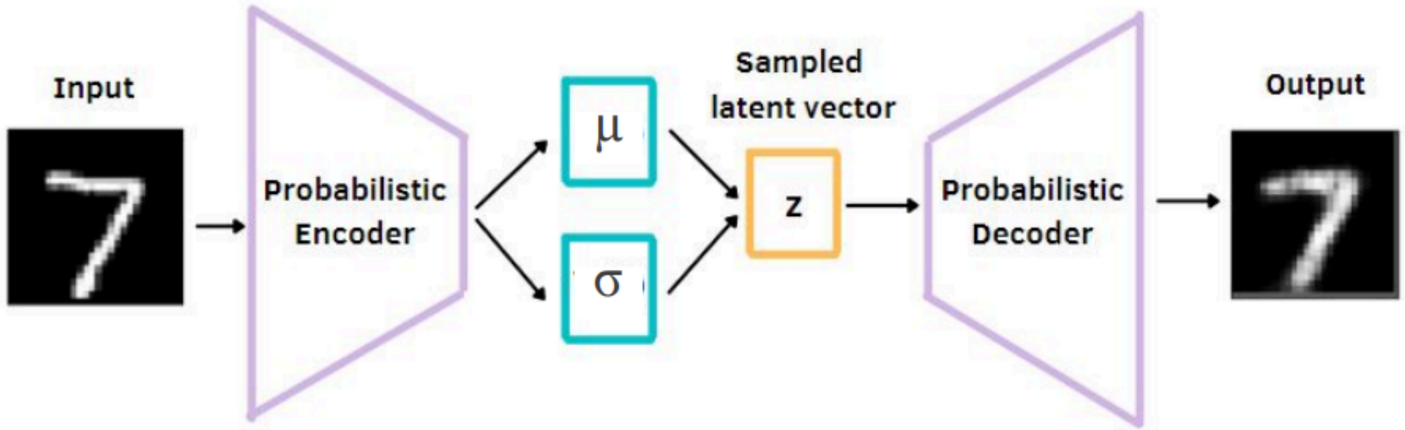




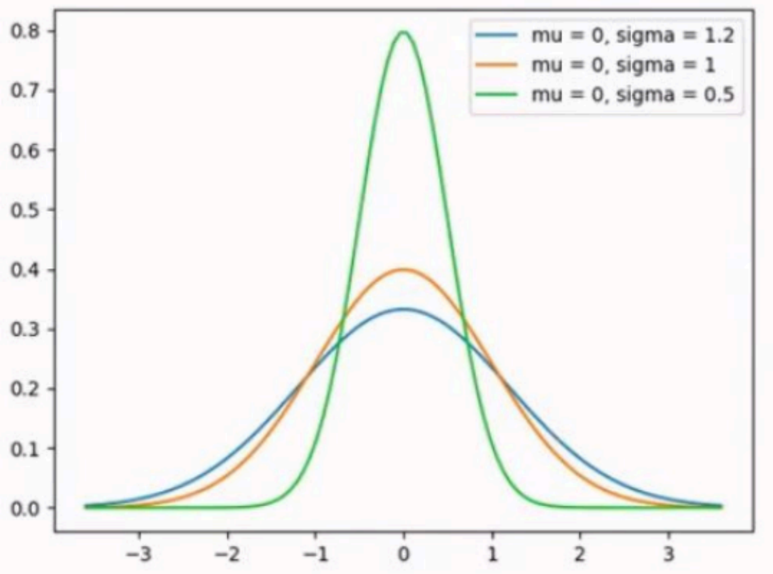
Better Alternative



Variational Autoencoders (VAE)



- Gaussian Distribution
  - $z \sim N(\mu, \sigma)$.
    - μ - mean
    - σ - standard deviation



What is **μ** (mu)?

- **μ** is the mean of the latent distribution.
  - Think of it as the center point or average of where the VAE believes the latent representation of your input should be.
- If your input is a "7", **μ** is saying:
  - "Most of the time, a good representation of this '7' is around here."

What is **σ** (sigma)?

- **σ** is the standard deviation — it tells us how spread out the values can be around the mean.
- A bigger **σ** means more randomness (wider spread); a smaller **σ** means less uncertainty.
- **σ** is saying:
  - There's some fuzziness around **μ** — here's how much you can vary."

Conditional Variational Autoencoder (CVAE)

- A CVAE is like a VAE, but with extra control.
- It learns to generate data based on a given condition
- VAE can generate new data, but:
  - It has no control over what it generates.
  - Outputs are random and not class-specific.
  - You can't ask it to “generate a 7” or “a happy face”.
- What if you want to generate:
  - A digit 3, not any digit?
  - A face with a certain emotion or identity?
  - A sentence with a specific style or topic?

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Thank You

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