Conditional Variational Autoencoder (CVAE) for Image Generation

Description:

This project leverages a Conditional Variational Autoencoder (CVAE) to generate RGB images conditioned on class labels. The CVAE combines the power of latent space representation with class-specific information, enabling the generation of realistic images tailored to different categories.

Impact:

Custom Image Generation: Allows the generation of specific types of images by conditioning on class labels, useful for data augmentation in machine learning tasks.

Improved Interpretability: The model provides insights into the relationships between latent space representations and class-specific features.

Practical Applications: Can be used in creative industries, medical imaging, or any domain requiring class-specific image generation.

Techniques and Libraries Used:

Deep Learning Framework: TensorFlow and Keras for building and training the CVAE.

Data Preprocessing: NumPy and PIL for image resizing, normalization, and handling.

Latent Space Sampling: Reparameterization trick using Keras backend to ensure differentiability during training.

Visualization: Matplotlib for displaying generated images and interactive sliders using ipywidgets.

Key Features:

Data Preparation:

Resized RGB images to 32x32 pixels and normalized pixel values to [0, 1].

Created one-hot encodings for class labels, enabling conditional generation.

Model Architecture:

Encoder: Maps input images to a latent space, learning the mean and variance of latent vectors.

Decoder: Reconstructs images from latent vectors and class labels.

Conditional Input: Incorporates class labels directly into both encoder and decoder pipelines.

Loss Functions:

Reconstruction Loss: Measures how well the generated images match the input images.

KL Divergence: Regularizes the latent space, encouraging it to approximate a Gaussian distribution.

Interactive Image Generation:

Allows users to generate random images using sliders to control the number of generated samples.

Supports both unconditional and class-conditioned image generation.

Visualization:

Generated images are displayed interactively with clear differentiation between classes.

Provides a user-friendly way to explore the latent space and visualize results.

Example Use Case:

Imagine a scenario where a designer needs sample images for different product categories. The CVAE can generate tailored images for each category, saving time and effort in manual design processes.

Summary:

This project demonstrates a sophisticated application of Variational Autoencoders for conditional image generation. By integrating latent space sampling and class-specific conditioning, it provides a versatile tool for generating high-quality, class-representative images.