📄 Project Documentary: FHE-Based Biological Age Predictor

This project predicts a person’s biological age using DNA methylation beta values from 100 CpG sites. It applies a Fully Homomorphic Encryption (FHE) pipeline using Concrete ML to ensure privacy-preserving inference. The final result is deployed as a Gradio web app on Hugging Face Spaces.

# 🧠 Overview

The pipeline has two parts:  
- train\_and\_save\_model.py: Builds, trains, and compiles the model.  
- app.py: Loads the model and handles encrypted inference via Gradio.

# 📁 Code Structure & Explanation

## 1. train\_and\_save\_model.py – 🔧 Model Training & Compilation

This script:  
- Simulates methylation input data (200 samples × 100 CpG values)  
- Applies standard scaling  
- Trains a LinearRegression model using Concrete ML  
- Compiles the model for FHE-compatible execution  
- Saves both the compiled model and the scaler in a directory

## 2. app.py – 🧪 Encrypted Inference via Gradio

This script:  
- Loads the previously compiled model and scaler  
- Accepts 100 CpG methylation values from a text box input (comma-separated)  
- Preprocesses the input using the scaler  
- Executes encrypted inference using the model (fhe="execute")  
- Displays the predicted biological age in a user-friendly interface

## 3. dna\_clock.R & install.R – 🔬 Optional R Integration

These R scripts demonstrate integration with the dnaMethyAge package, enabling reference biological clock calculations (e.g., Horvath Clock).  
- install.R installs dependencies via devtools  
- dna\_clock.R runs the Horvath clock and saves output as CSV

## 4. requirements.txt – 📦 Python Dependencies

Specifies the Python environment needed to run the app:  
- streamlit (optional, not used in final deployment)  
- gradio  
- concrete-ml  
- scikit-learn  
- numpy  
- pandas  
- rpy2 (optional for R integration)

# 🌐 Deployment

The app is deployed on Hugging Face Spaces using Gradio.  
Live Demo: https://huggingface.co/spaces/CAT-ROM/fhe-biological-age-predictor

# 📬 Author & Credits

Developed by me (Roshini) as part of the Zama AI Bounty #143 challenge.  
Inspired by scientific research on epigenetic clocks including Horvath, DunedinPACE, and others.