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Our Final Project
Cloud Computing Project:
Playing Federated Learning with Docker
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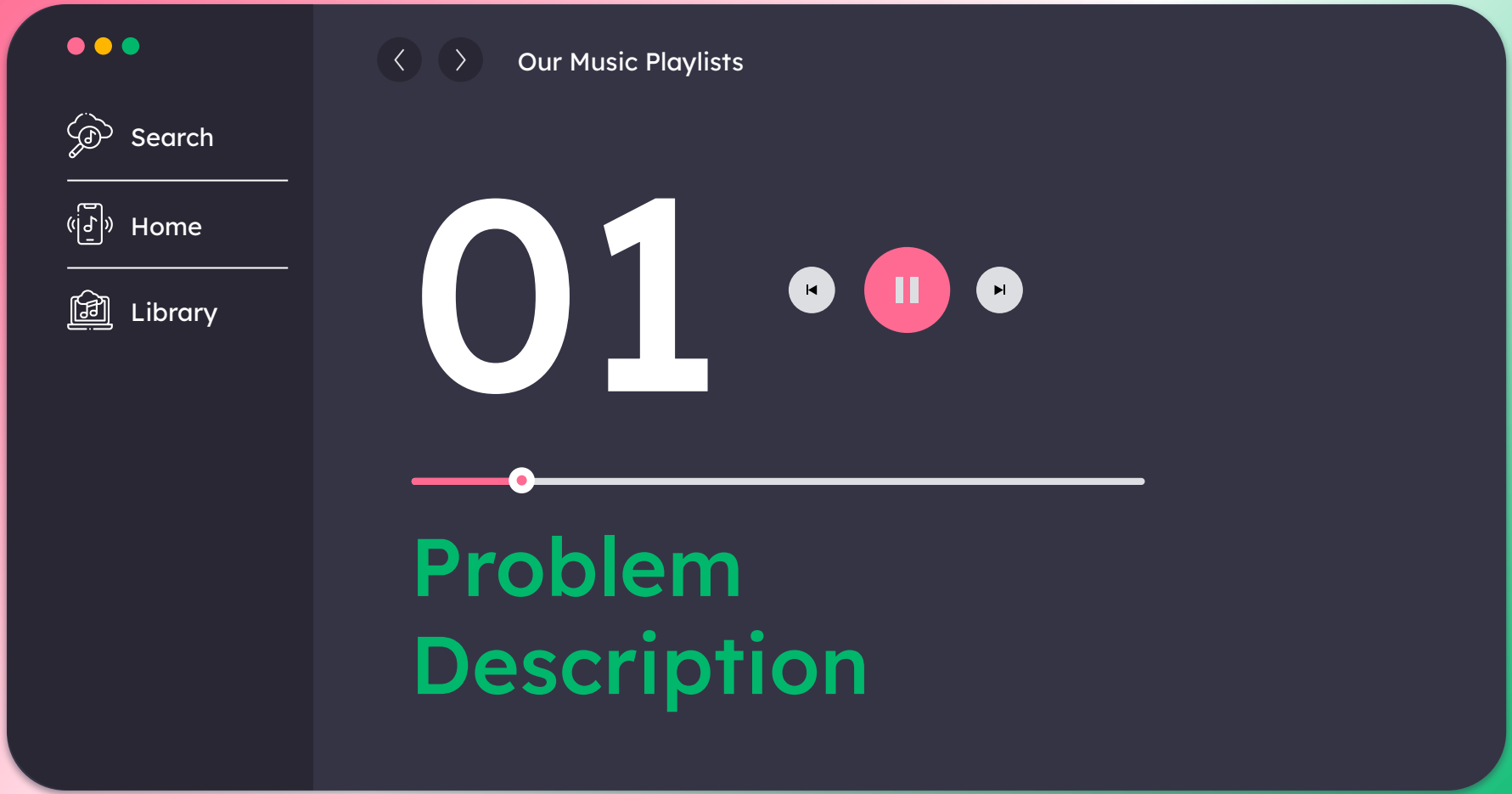
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Problem
Description

Master Slave Architecture

Master-Slave Architecture: Our study utilizes a master-slave architecture for federated learning. The master node oversees the process, handling logistic regression model weights and aggregating slave nodes' updates.

Obstacles: Traditional machine learning faces challenges in era-based song classification, particularly concerning data privacy and security due to sensitive music data.

Federated Learning: Federated learning, a decentralized approach, provides the solution. It allows multiple parties to collaboratively build models while ensuring data privacy and regulatory compliance, ideal for handling sensitive song data securely.

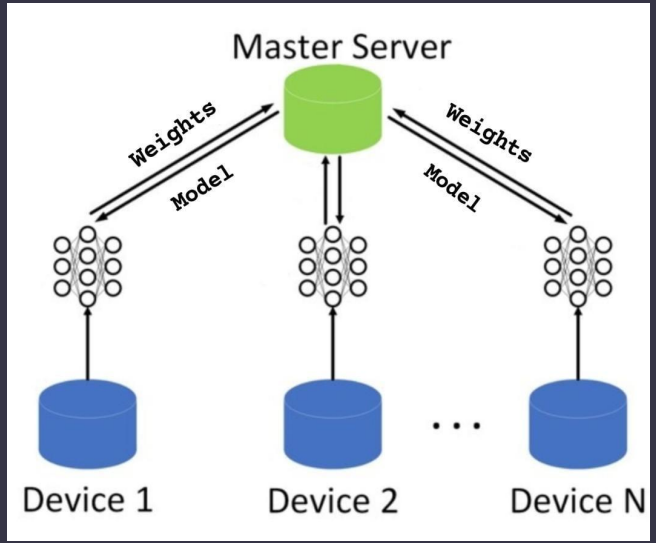
Central Challenge: Our primary challenge is classifying songs into historical eras, crucial for applications like music recommendation, historical analysis, and content curation.

Introduction to the Problem and Federated Learning

Data Security: Slave nodes independently process their data subsets, maintaining data privacy and security throughout the model-building process.

Docker for Weight Distribution: Docker efficiently transfers model weights to client nodes while enhancing data privacy through encapsulation and isolation, preventing data leaks.

Cloud Deployment: Utilizing cloud environments like AWS ensures scalability, accessibility, and secure collaboration among client nodes, meeting stringent data security requirements.



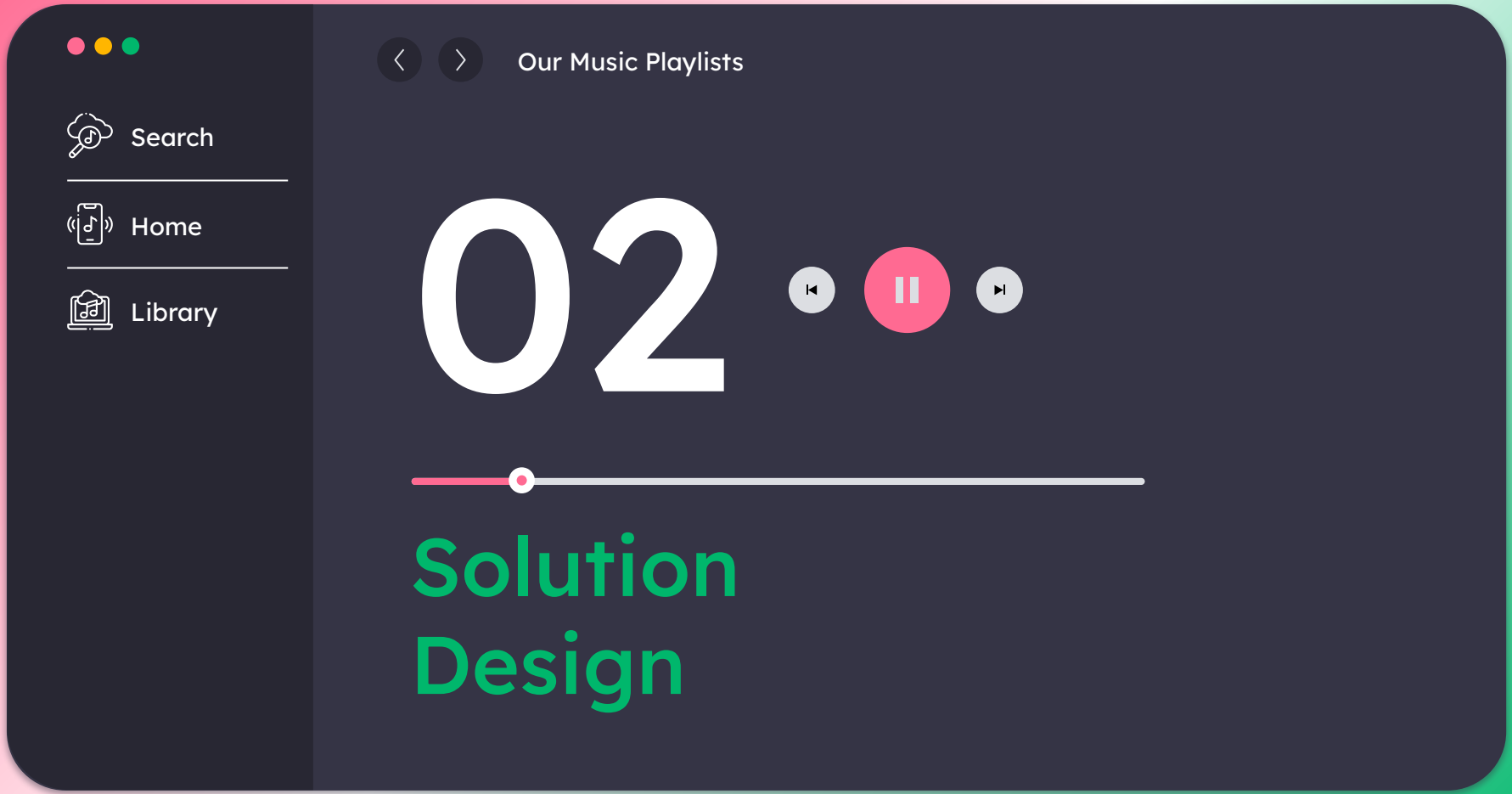
A look of the dataset

We are printing the first 10 rows of our dataset to get a quick glimpse of the data and understand its structure. Is important to say that we grouped two decades to have our final 3 classes: X-Generation(60s-70s), Y-Generation(80s-90s) and Z-Generation(00s-10s)

```
df.iloc[:,1:].head(10)
```

✓ 0.0s

	track_name	decade	danceability	energy	key	loudness	mode	speechiness	acousticness	instrumentalness	liveness	valence	tempo
0	Pump Up The Jam	Y-Generation	0.885	0.844	10	-9.225	0	0.0733	0.01470	0.000004	0.0494	0.715	124.602
1	All Outta Angst	Y-Generation	0.637	0.969	0	-4.682	1	0.0432	0.00473	0.001480	0.0428	0.940	100.260
2	Walkin' On The Sun	Y-Generation	0.735	0.974	6	-4.636	1	0.0318	0.43000	0.000000	0.1450	0.967	123.290
3	54	Y-Generation	0.793	0.681	6	-6.562	0	0.0477	0.02150	0.000612	0.0863	0.792	111.011
4	Beautiful Day	Y-Generation	0.539	0.926	2	-6.495	1	0.0499	0.01400	0.001360	0.3600	0.454	136.279
5	Show Me the Meaning of Being Lonely	Y-Generation	0.630	0.625	6	-5.088	0	0.0252	0.23100	0.000000	0.0765	0.683	167.998
6	Dil Hai Ke Manta Nahin	Y-Generation	0.499	0.534	8	-9.081	1	0.0316	0.87700	0.002820	0.1950	0.717	117.524
7	Sunny Came Home	Y-Generation	0.554	0.566	11	-8.050	0	0.0332	0.33000	0.010000	0.0943	0.418	167.880
8	Pichakappoomkaavukalkkum	Y-Generation	0.788	0.844	0	-5.179	1	0.2630	0.68200	0.000080	0.1510	0.917	81.700
9	Humpin' Around	Y-Generation	0.710	0.800	1	-7.141	1	0.0400	0.00223	0.211000	0.0455	0.610	110.211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Design

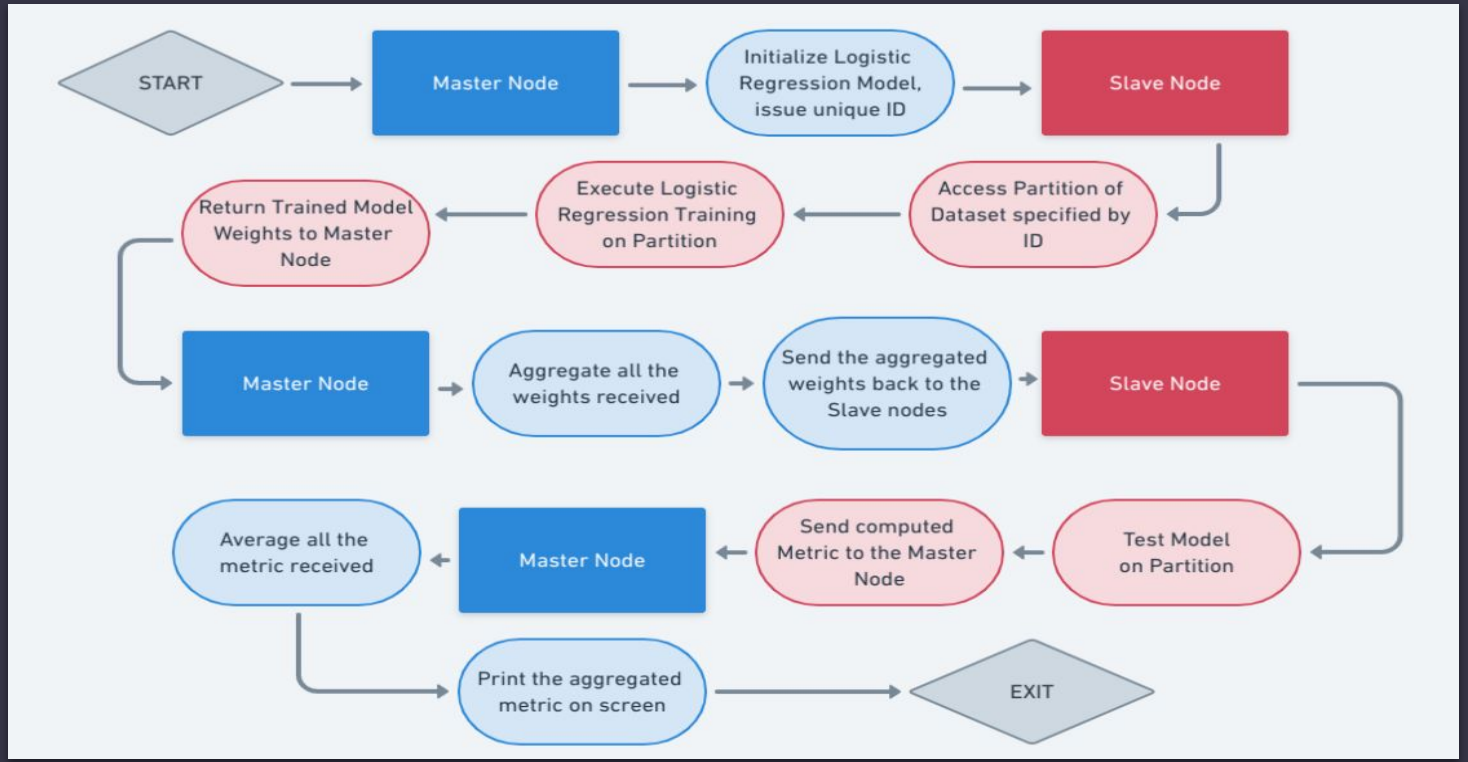
Architecture Overview

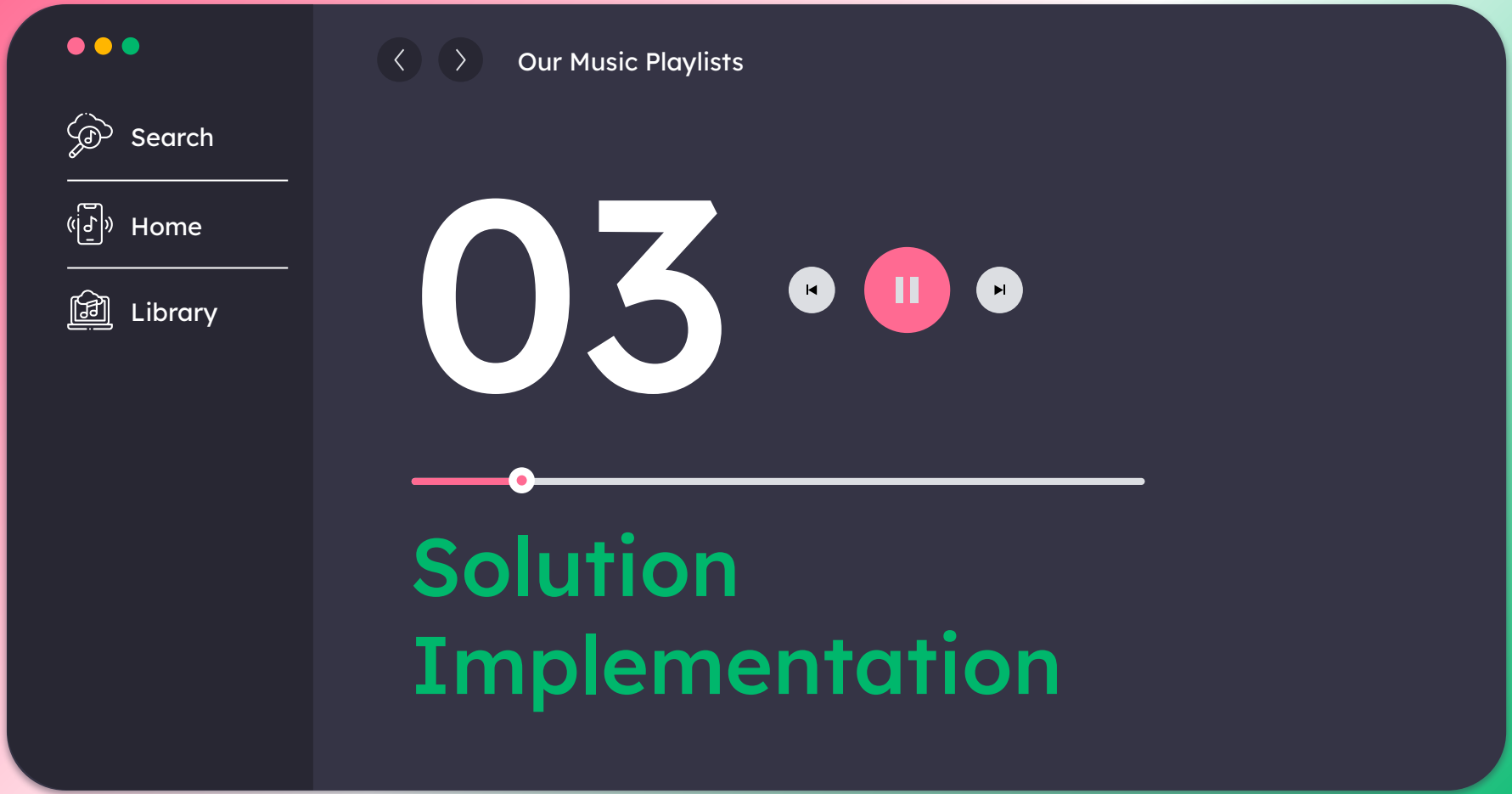
Master node coordinates the federated learning process.

- Master sends initial model weights and unique IDs to each slave node.
- Master initiates the process by initializing a logistic regression model and ensures all slave nodes start with the same initial model.
- Slave nodes access dataset partitions specified by their IDs.
- Slave nodes perform logistic regression training on their partitions.
- Slave nodes return trained model weights to the master.
- Master aggregates weights to obtain the most recent model and sent back to slaves.
- Slave nodes test the new model on their dataset divisions.
- Slave compute a metric and submit it to the master.
- Master node computes the average metric when all slave nodes submit their results.
- The federated learning program prints the final model measure on the screen.

With the optimized model, the master node assigns songs to their respective decades.

Architecture Overview

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Implementation



Docker Containers: Docker is used to create isolated environments for both the master and slave nodes, ensuring reproducibility and scalability.

Communication:

- To enable communication between master and slave nodes, a well-defined RESTful API is established using Flask for the master node.
- The slave nodes send HTTP requests to the master node's API to retrieve instructions and submit results.

Master Node Implementation:

- "/get model", method = 'GET': Slave requests initialized or updated Logistic Regression Model, receives unique ID assigned by master.
- "/get model", method = 'POST': Slave sends trained model coefficients to the masterfor aggregation.
- "check server", method = 'GET': Slave checks if it can request the updated model, ensuring synchronization.
- "test model", method = 'POST': Slave sends test metrics for averaging.

Technical Details:

- Locking mechanism using Python object Mutex to prevent data collision.
- Unique IDs stored in a queue, emptied when a slave enters the Federated Learning process.
- Weights stored in Numpy arrays for aggregation.
- Counters for tracking slave progress.

Slave Node Implementation:

- Python client script.
- Communicates with the master through RESTful API services.

Data Handling:

- Pandas module for loading and reading CSV partitions.
- Custom Logistic Regression Model built from scratch to ensure consistency.

Benefits:

Privacy-Preserving Scalability Consistency Accurate Classification

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Deployment of Solution

Docker Compose

Deployment Process:

- Use of AWS EC2 instances for Federated Learning application.
- Script to set the number of slave nodes and scale partitions.
- Docker images for Master and Slave nodes.
- Dataset partitioning.

```
#!/bin/bash
export NUM_SLAVES=10
cd Master
docker build -t master_image .
python3 create_partitions.py
cd Slave
docker build -t slave_image .
cd ..
docker-compose up -d --scale slave=$NUM_SLAVES
```

Deploying Federated Learning on AWS EC2 Instances

Deployment Process: Finally it deploys the containers via Docker Compose

```yaml
version: '3'
services:
  master:
    image: master_image
    networks:
      - fed_network
    environment:
      - NUM_SLAVES=${NUM_SLAVES}

  slave:
    image: slave_image
    networks:
      - fed_network
    depends_on:
      - master


networks:
  fed_network:
    driver: bridge
```

AWS EC2 Configuration

We launched multiple the same EC2 istance, with these characteristics:

- Amazon Machine Image: Amazon Linux
- Instance Type: t2.large.
- Security Group with specific inbound rules.
- User Data script for initialization.

```
#!/bin/bash
sudo yum -y update
sudo yum -y install docker python pip
service docker start
usermod -a -G docker ec2-user
chkconfig docker on
```

Application Setup:

- Install required dependencies: docker-compose and pandas.
- Download the application files an S3 bucket.
- Configure the number of slave nodes.
- Execute the application.

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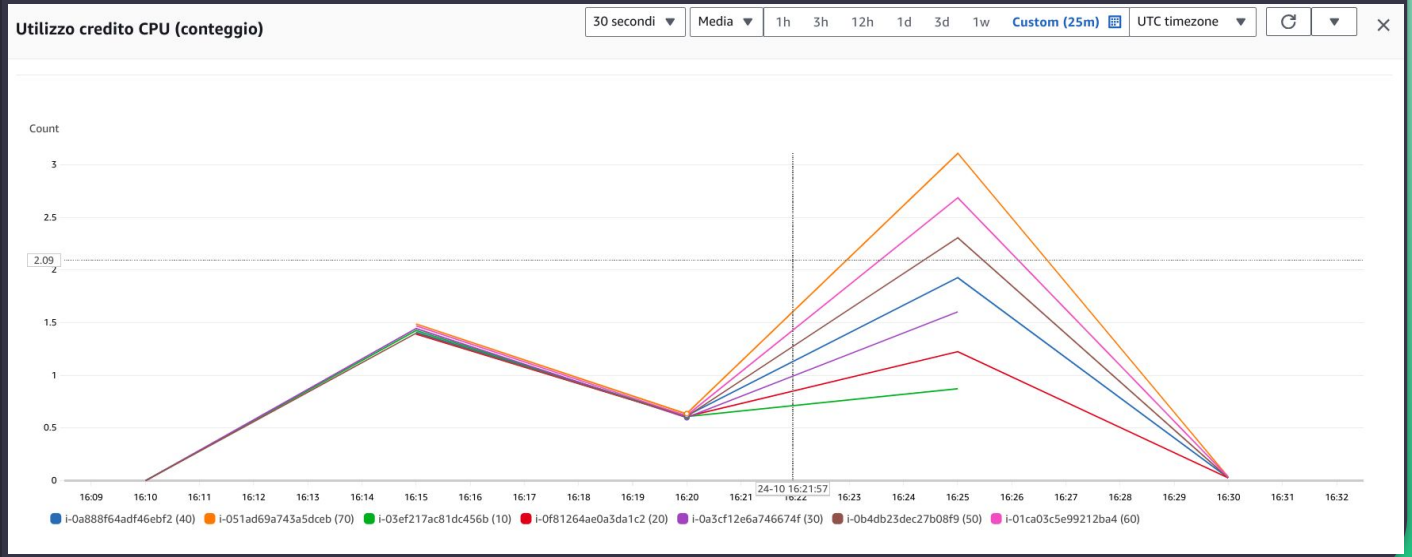
Experimental Design and Solution

AWS CloudWatch Monitoring and Scalability

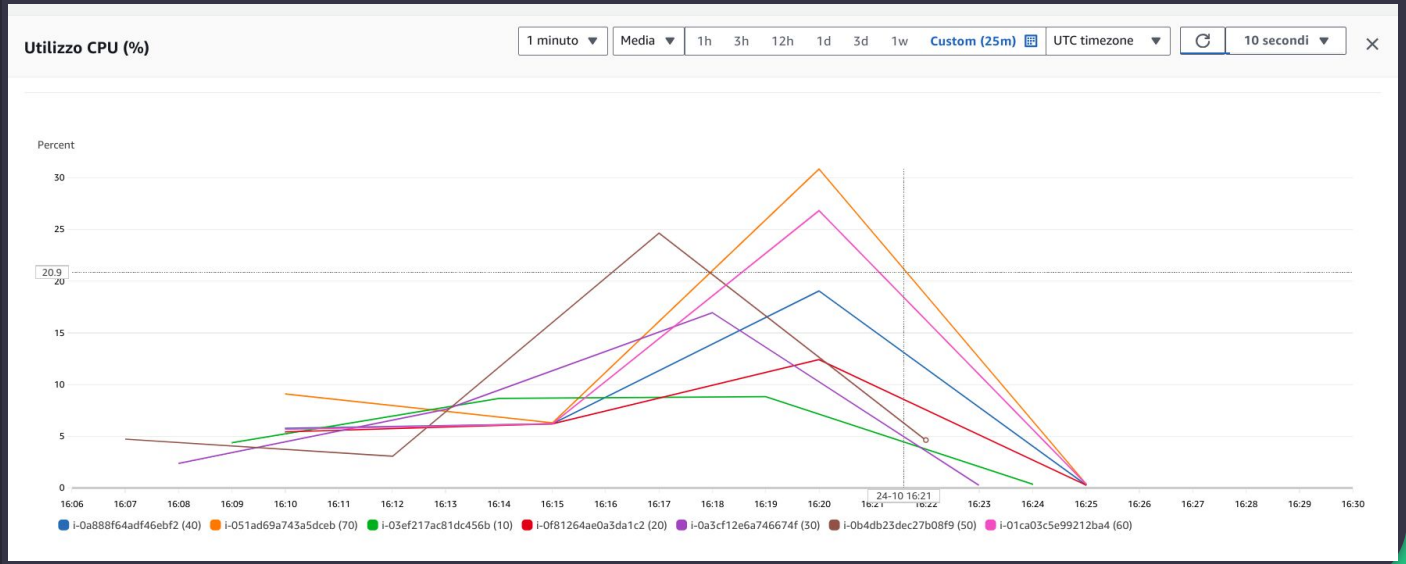
AWS CloudWatch Monitoring:

- Monitored CPU Credit Usage and CPU Usage throughout the application's execution.
- Data collected from the initialization of EC2 instances to application termination.



CPU Usage and Scalability:

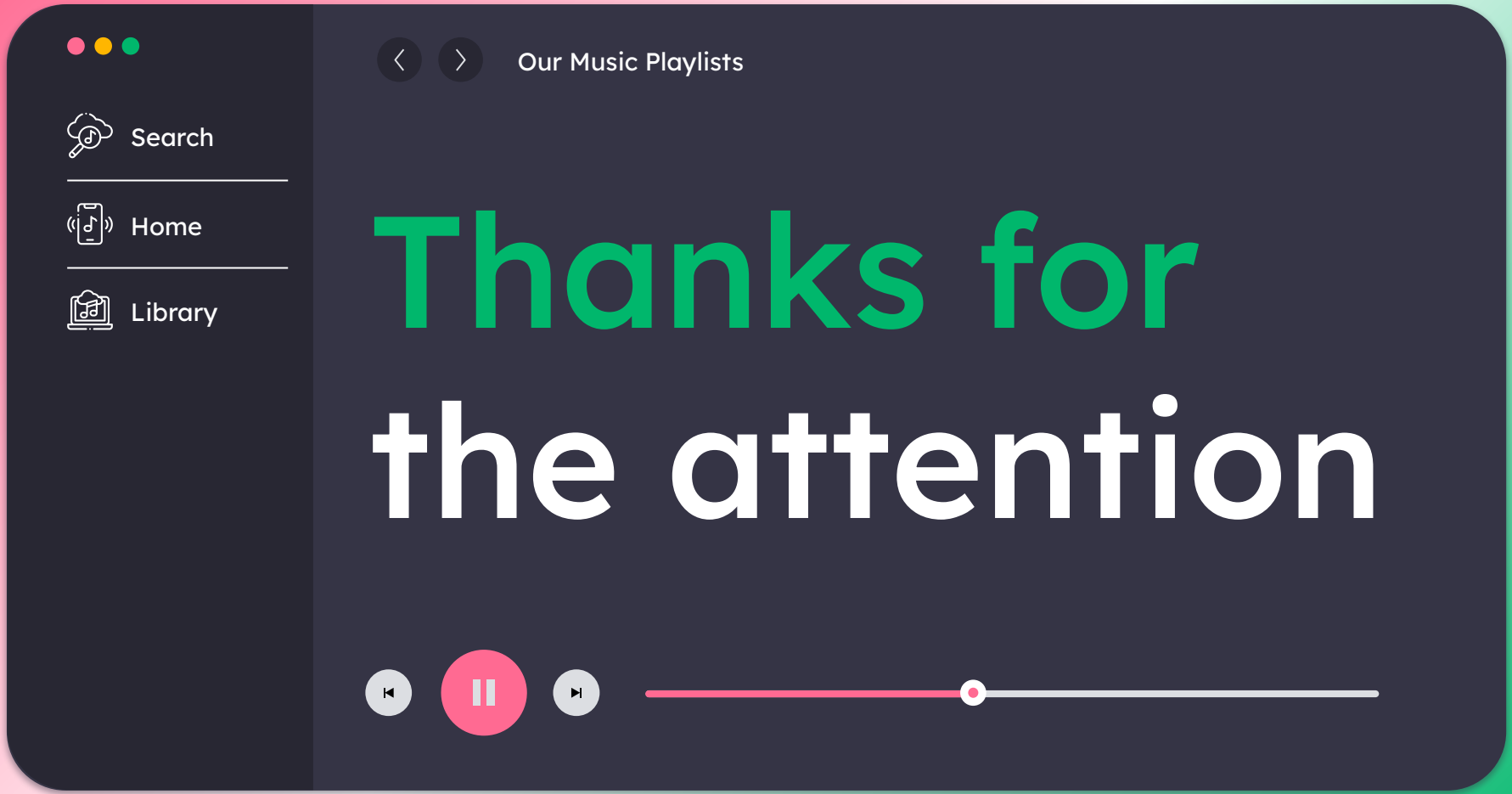
- CPU Usage for EC2 instances:
- 10 nodes (green line) reached a maximum of 10% CPU usage.
- 70 nodes (orange line) achieved a maximum of 30% CPU usage.
- The application optimally utilizes computational resources.
- Shows potential for scaling with increased nodes, indicating excellent scalability.



Future Developments

Plans for a secondary web service in the master node:

- Allow users to utilize the Federated Learning model.
- User input: Song name from Spotify.
- Model output: Predicted decade of the song's belonging.
- Expected accuracy of 66% based on training.
- Application demonstrates efficient use of AWS resources.
- Scalable for varying numbers of nodes.
- Future expansion to provide song decade predictions for users.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