MLOps Iris Classification – End to End Pipeline

Group No: 70

Name	ID	Contribution(%)
Dhiman Kundu	2023ac05129	100
Rina Gupta	2023ac05028	100
Sarit Ghosh	2023ac05131	100
Soumen Choudhury	2023ac05143	100

Assignment Tasks

This project implements a comprehensive MLOps implementation for Iris flower classification with automated training, monitoring, and deployment capabilities addressing the following assignment requirements:

Part 1: Repository and Data Versioning

- **GitHub Repository**: Complete project hosted on GitHub with clean structure
https://github.com/SaritGhoshBits25/MLOps_Assignment_Group70
- **Docker Hub Repository**:
https://hub.docker.com/r/wp1412011989/iris-api

- **Data Loading & Preprocessing**: Automated data preprocessing pipeline (`src/data_preprocessing.py`)

Directory Structure: Well-organized project structure with separate directories for source code, data, models, tests, and monitoring

```
├── src/                          # Source code
│   ├── api.py                    # FastAPI application with monitoring
│   ├── train.py                  # Model training with MLflow
│   ├── data_preprocessing.py     # Data preprocessing pipeline
│   ├── database.py               # Database operations and logging
│   └── retrain_pipeline.py       # Automated retraining pipeline
├── data/                         # Dataset files
│   ├── iris_raw.csv              # Raw iris dataset
│   ├── iris_train.csv            # Training data
│   └── iris_test.csv             # Test data
```

```
├── models/                 # Trained model artifacts
├── tests/                  # Test suite
├── monitoring/             # Monitoring configuration
│   └── prometheus.yml      # Prometheus configuration
├── .github/workflows/      # CI/CD pipeline
│   └── ci-cd.yml           # GitHub Actions workflow
├── Dockerfile              # Container configuration
├── docker-compose.yml      # Multi-service orchestration
└── requirements.txt        # Python dependencies
```

Data Version Control (DVC):

This project uses DVC for data versioning and pipeline management. DVC tracks data files and ensures reproducible data processing workflows.

- **Data tracking**: Raw iris dataset (`data/iris_raw.csv`)
- **Pipeline**: Automated data preprocessing pipeline
- **Remote storage**: Local remote for data versioning

DVC Files Structure

```
├── .dvc/
│   └── config          # DVC configuration
├── data/
│   ├── .gitignore      # Git ignores data files
│   ├── iris_raw.csv.dvc  # DVC tracks raw data
│   ├── iris_train.csv    # Generated by pipeline
│   └── iris_test.csv     # Generated by pipeline
├── dvc.yaml            # Pip`eline definition
```

Part 2: Model Development & Experiment Tracking

Multiple Models: Implementation of classification models:

- Logistic Regression
- Random Forest
- Support Vector Machine (SVM)

Model Information:

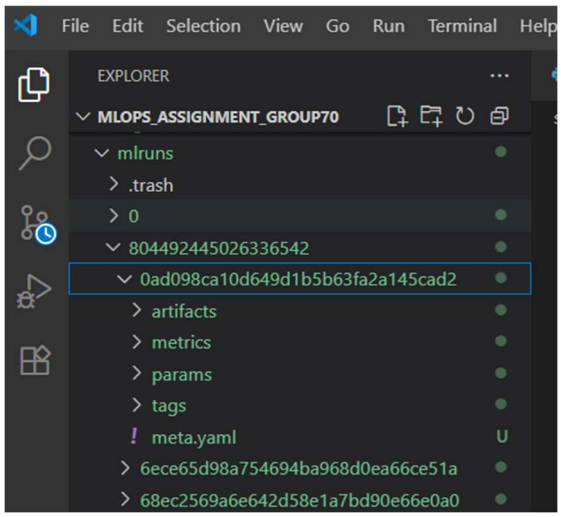
- **Dataset**: Iris flower classification
- **Features**: Sepal length/width, Petal length/width
- **Classes**: Setosa, Versicolor, Virginica
- **Models**: Logistic Regression, Random Forest, SVM
- **Evaluation**: Accuracy, Precision, Recall, F1-score

MLflow Integration:

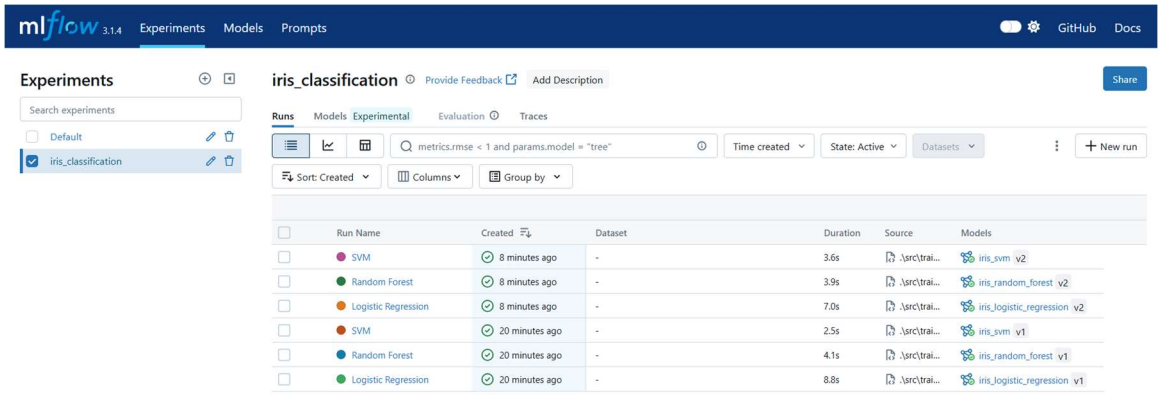
- Experiment tracking with parameters and metrics (`src/train.py`)
- Model versioning and artifact storage
- Model registry for best model selection

Following directories are created by MLflow under mlruns/<experiment-id>/<run-id>/:

- params/: model hyperparameters
- metrics/: performance metrics
- artifacts/: saved models
- tags/: metadata like model name or author



- MLflow UI accessible at `**http://localhost:5000**`

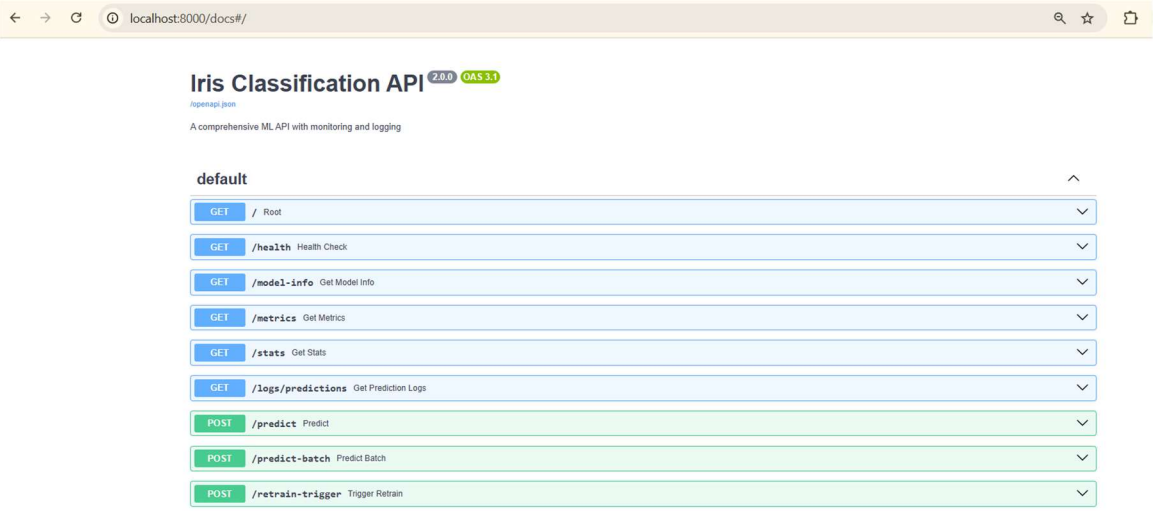


- **Model Selection**: Automated best model selection based on performance metrics

Part 3: API & Docker Packaging

FastAPI Implementation: High-performance REST API (`src/api.py`) with:

- Automatic API documentation with Swagger UI
- GET / - API information and status
- GET /health - Health check endpoint
- POST /predict - Make predictions single predictions
- POST /predict/batch - Batch predictions for batch predictions
- GET /model/info - Current model information
- GET /metrics - Prometheus metrics
- POST /retrain-trigger – Retrain Model

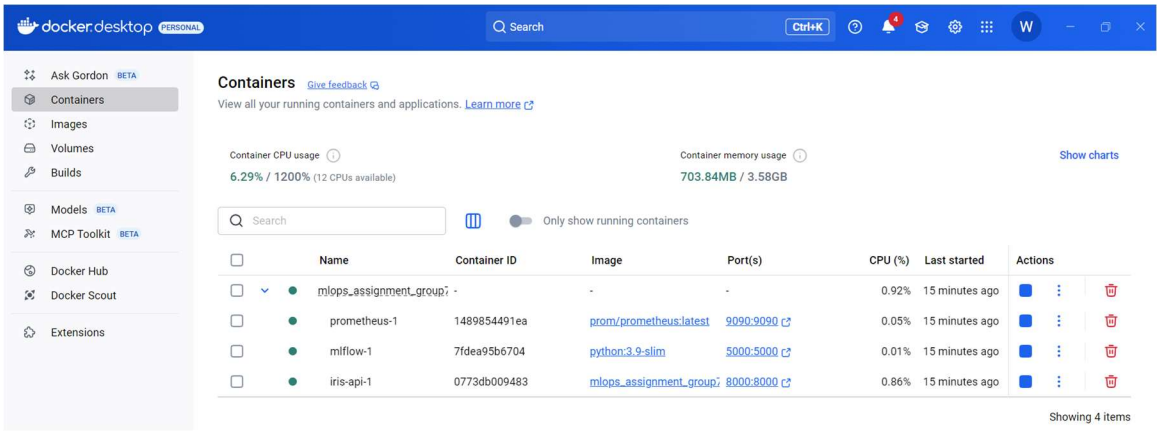


Pydantic schemas are used for request validation.

Docker Containerization: This is fully containerized using Docker.

- Multi-stage Dockerfile for optimized images
- Docker Compose orchestration (`docker-compose.yml`)
- Health checks and restart policies
- Build and run with Docker Compose

```
docker-compose up –build
```

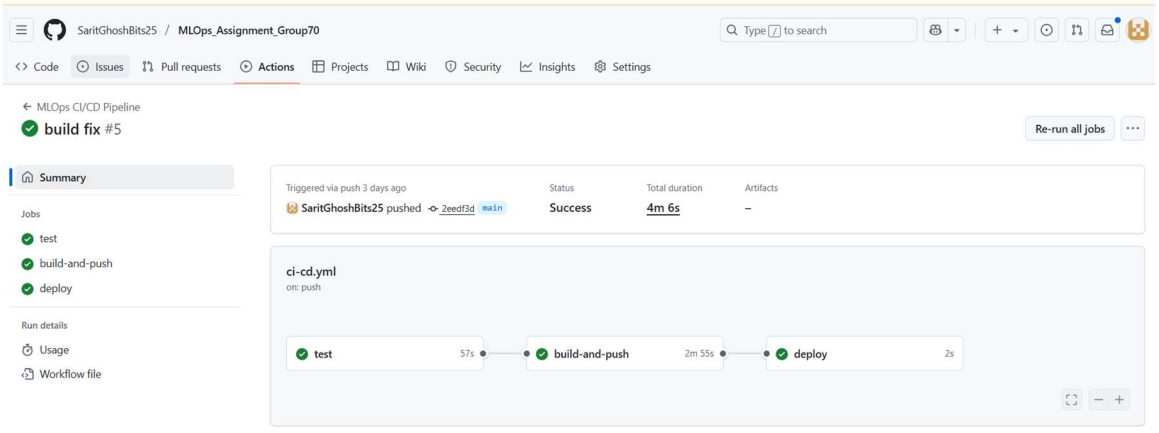


This will start:

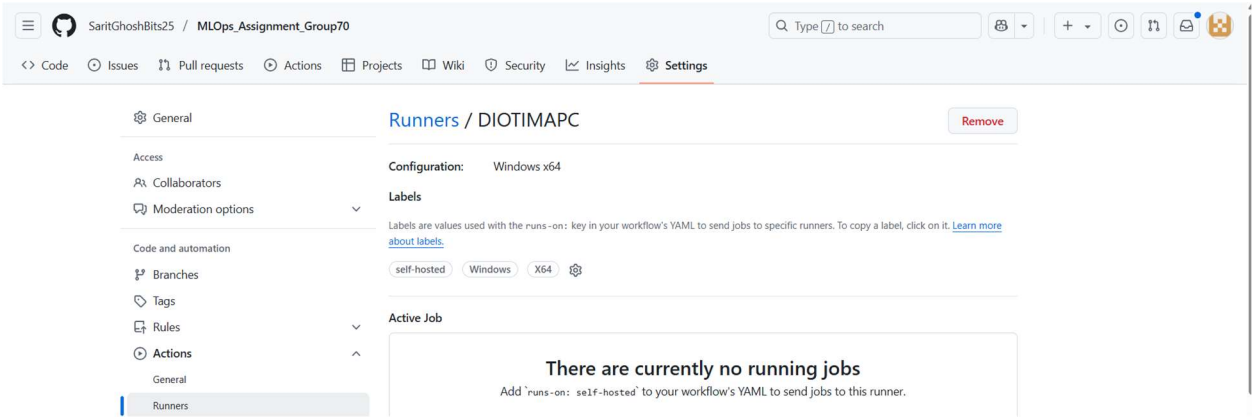
- **Iris API:** http://localhost:8000
- **Prometheus:** http://localhost:9090
- **MLflow:** http://localhost:5000
- **JSON Input/Output**: Structured JSON request/response format with validation

Part 4: CI/CD with GitHub Actions

- **Automated Pipeline** (`.github/workflows/ci-cd.yml`):
- **Testing Stage**: Code linting, unit tests, and API health verification
- **Build Stage**: Docker image building and container testing
- **Deploy Stage**: Automated deployment with health monitoring
- **Code Quality**: Automated linting and testing on every push
- **Docker Hub Integration**: Automated image building and registry push



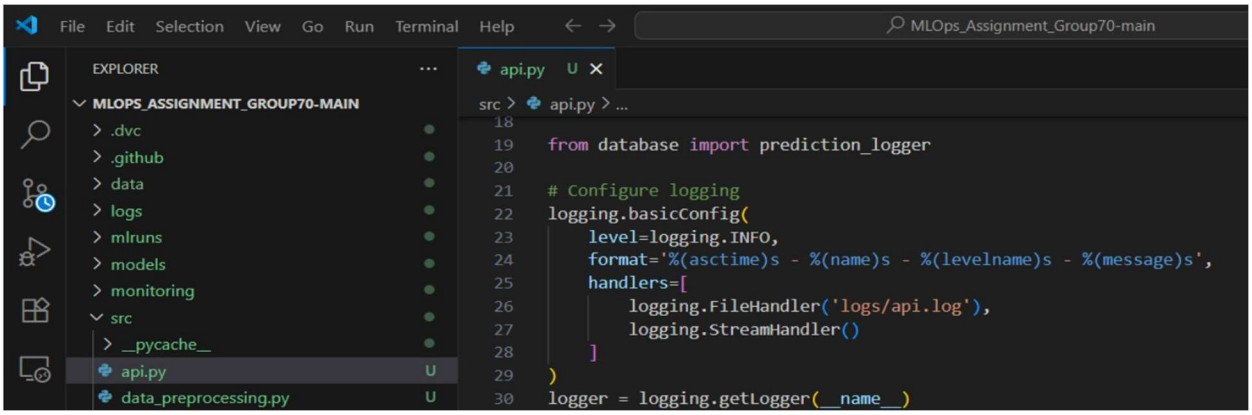
- **Deployment**: Local deployment with self-hosted runner



Part 5: Logging and Monitoring

Comprehensive Logging:

- API logs: src\api.py



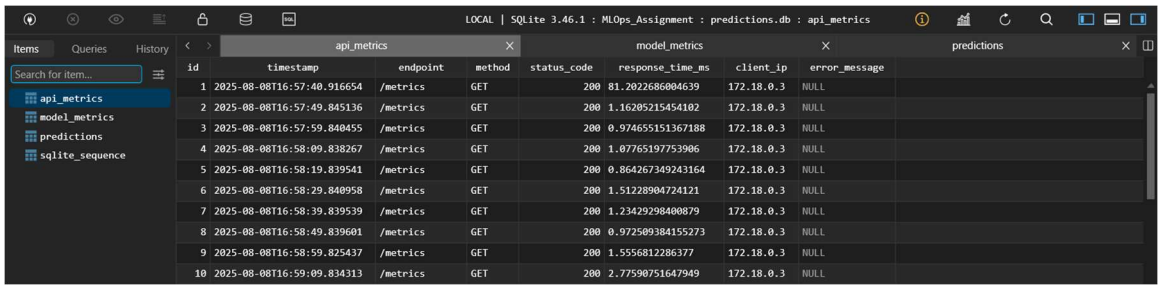
API Logging:

```
INFO:     Will watch for changes in these directories: ['/app']
INFO:     Uvicorn running on http://0.0.0.0:8000 (Press CTRL+C to quit)
INFO:     Started reloader process [1] using StatReload
INFO:database:Database initialized successfully
/usr/local/lib/python3.9/site-packages/pydantic/_internal/_fields.py:149: UserWarning: Field "model_version" has conflict with protected namespace "model_".

You may be able to resolve this warning by setting `model_config['protected_namespaces'] = ()`.
  warnings.warn(
/usr/local/lib/python3.9/site-packages/pydantic/_internal/_fields.py:149: UserWarning: Field "model_accuracy" has conflict with protected namespace "model_"
.

You may be able to resolve this warning by setting `model_config['protected_namespaces'] = ()`.
  warnings.warn(
INFO:     Started server process [26]
INFO:     Waiting for application startup.
INFO:api:Model loaded successfully
INFO:api:Scaler loaded successfully
INFO:api:Model info loaded successfully
INFO:api:API startup completed
INFO:     Application startup complete.
INFO:     172.18.0.4:59192 - "GET /metrics HTTP/1.1" 200 OK
INFO:     172.18.0.4:51764 - "GET /metrics HTTP/1.1" 200 OK
INFO:     172.18.0.1:53216 - "GET /docs HTTP/1.1" 200 OK
INFO:     172.18.0.1:53216 - "GET /openapi.json HTTP/1.1" 200 OK
INFO:     172.18.0.4:44358 - "GET /metrics HTTP/1.1" 200 OK
INFO:     172.18.0.4:45126 - "GET /metrics HTTP/1.1" 200 OK
INFO:     172.18.0.4:49388 - "GET /metrics HTTP/1.1" 200 OK
```

- **Container logs:** docker-compose logs <service-name>
- **MLflow logs:** Available in MLflow UI

All predictions are logged to SQLite database for persistence storage with (`src/database.py`):

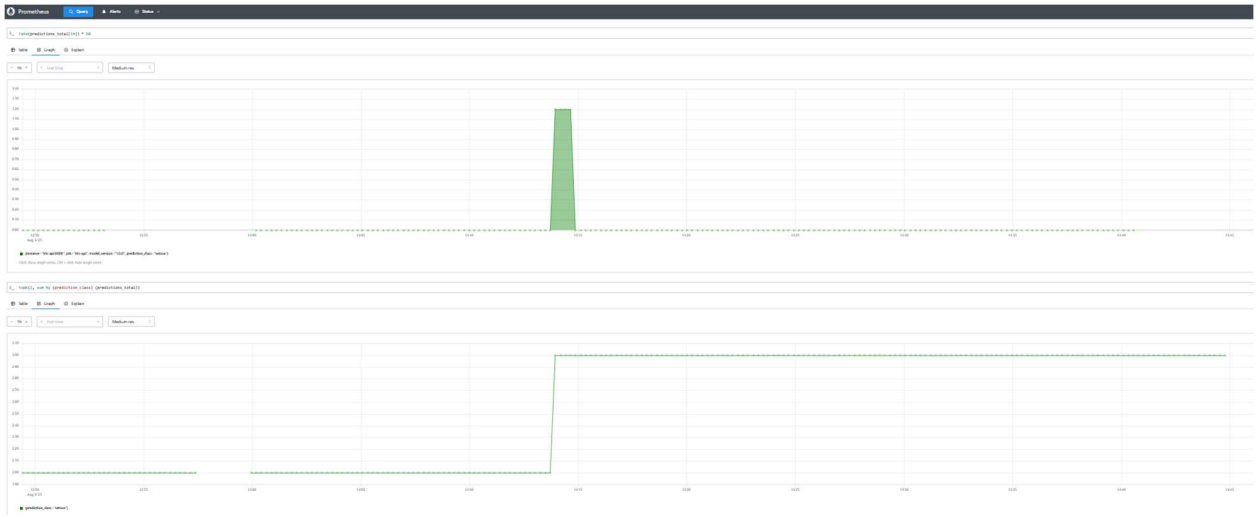
- Prediction ID and timestamp
- Input features and predictions
- Model version and confidence scores
- Request metadata



id	timestamp	endpoint	method	status_code	response_time_ms	client_ip	error_message
1	2025-08-08T16:57:40.916654	/metrics	GET	200	81.2022686004639	172.18.0.3	NULL
2	2025-08-08T16:57:49.845136	/metrics	GET	200	1.16205215454102	172.18.0.3	NULL
3	2025-08-08T16:57:59.840455	/metrics	GET	200	0.974655151367188	172.18.0.3	NULL
4	2025-08-08T16:58:09.838267	/metrics	GET	200	1.07765197753906	172.18.0.3	NULL
5	2025-08-08T16:58:19.839541	/metrics	GET	200	0.864267349243164	172.18.0.3	NULL
6	2025-08-08T16:58:29.840958	/metrics	GET	200	1.51228904724121	172.18.0.3	NULL
7	2025-08-08T16:58:39.839539	/metrics	GET	200	1.23429298400879	172.18.0.3	NULL
8	2025-08-08T16:58:49.839601	/metrics	GET	200	0.972509384155273	172.18.0.3	NULL
9	2025-08-08T16:58:59.825437	/metrics	GET	200	1.5556812286377	172.18.0.3	NULL
10	2025-08-08T16:59:09.834313	/metrics	GET	200	2.77590751647949	172.18.0.3	NULL

Monitoring Integration:

- Prometheus metrics endpoint (`/metrics`)
- Custom metrics for predictions, latency, and model performance
- Prometheus configuration (`monitoring/prometheus.yml`)



Health Monitoring: Dedicated health check endpoints for system status

Part 6: Summary + Demo

- **Architecture Documentation**: Comprehensive summary with system architecture
- **Demo Preparation**: Complete setup instructions and API usage examples
- **Video Walkthrough**: Ready-to-demonstrate solution with all components integrated

Bonus Features

Input Validation:
- Pydantic models for request/response validation
- Schema-based input validation with error handling

Prometheus Integration:
- Full Prometheus monitoring setup
- Custom metrics dashboard ready
- Real-time performance monitoring

Model Retraining via API:
The '/retrain' endpoint supports:
- Automated retraining pipeline (`src/retrain_pipeline.py`)
- Performance-based retraining triggers
- Continuous model improvement workflow
- Retraining the best model
- Logging it to MLflow
- Saving the new model to registry