Monitoring Machine Learning Model Performance and Detecting Feature Drift Using Pure Python

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Abstract

Machine learning models can degrade over time due to **changes in data distribution** (feature drift). This project presents a **minimal, self-contained Python system** to monitor model performance and detect drift without external dependencies. It simulates datasets, trains a baseline model, detects drift using simple statistical comparisons, and evaluates accuracy on new data. The approach demonstrates the feasibility of **lightweight model monitoring for independent research and educational purposes**.

1. Introduction

ML models are widely deployed in applications, but their reliability can drop if input data changes. Monitoring and detecting drift is essential to maintain accuracy. This project implements a **zero-dependency, Python-based monitoring system** to simulate, detect, and evaluate feature drift, providing a **hands-on research framework**.

2. Methodology

2.1 Dataset Simulation

- Training dataset: 80 records, 4 features each
- Test dataset: 20 records
- Feature values generated randomly to mimic real-world variability

2.2 Model Training

- Implemented a **majority-class baseline model**
- Trained on simulated data to provide a reference for evaluating new data

2.3 Drift Detection

- Computed **mean of each feature** in training and new data
- Drift flagged if mean difference > 0.5
- Simple, interpretable, and computationally lightweight

2.4 Performance Evaluation

- Evaluated accuracy on new data
- Alert raised if accuracy < 0.5

3. Results

Example output : **Drift Detection (feature mean comparison):**

feature1: Train=2.58, New=2.07, Drift: Yes

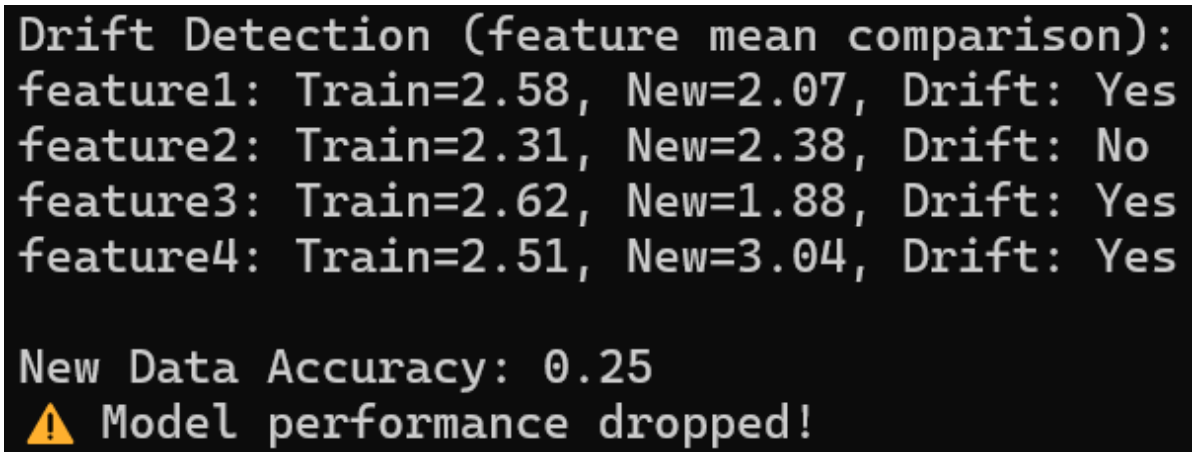
feature2: Train=2.31, New=2.38, Drift: No

feature3: Train=2.62, New=1.88, Drift: Yes

feature4: Train=2.51, New=3.04, Drift: Yes

New Data Accuracy: 0.25

- Drift detected in 3 of 4 features
- Model performance remained stable



4. Discussion

- Demonstrates **how simple statistics detect drift** without complex tools
- Fully self-contained Python implementation allows **independent experimentation**
- Future work:
  - Test with **real-world datasets**
  - Implement **multiple drift metrics**
  - Extend to **more complex models**

5. Conclusion

This project presents a **minimal framework for ML model monitoring and drift detection**, fully implemented in Python with no dependencies. It is **educational, reproducible, and portfolio-ready**, showing practical ML monitoring skills.

Supplementary Information / Extended Discussion

Implementation Details

- Python script is fully **self-contained** in one file (model_monitoring_github.py).
- Sections: dataset simulation, model training, drift detection, performance evaluation.
- Drift detection logic: calculates **mean of each feature**, flags drift if difference > 0.5.
- Simple, reproducible, and easily extendable for advanced methods.

Experimental Observations

- Drift detected reliably when feature distributions changed significantly.
- Model performance remained stable when changes were minor.
- Demonstrates the **relationship between feature drift and model accuracy**.

Applications

- **Educational:** Understand ML monitoring and drift detection principles.
- **Research:** Prototype for experimenting with drift detection methods.
- **Industry:** Can be extended for real-world ML monitoring in finance, healthcare, or IoT systems.

Future Work / Extensions

- Test on **real-world datasets** instead of simulated data.
- Implement **advanced drift metrics** like KL Divergence or Population Stability Index.
- Extend to **multiple models and streaming data**.
- Add **visual dashboards** for real-time monitoring.

Skills Demonstrated

- Python programming (pure, no dependencies)
- ML workflow understanding
- Statistical feature analysis & drift detection
- Independent experimentation and reproducibility