Faysal Aziz

Advanced AI & ML with Python

for Materials Engineers From fundamentals to autonomous agents and failure detection in materials imaging - 5 days

FA-0026 · 5 days

Agentic & Generative AI · Software Development · Data & Analytics

Introduction

Predictive technologies and computer vision are revolutionizing materials engineering, enabling unprecedented precision in design, analysis, and quality control. This intensive course builds from Python fundamentals and machine learning principles to advanced agentic AI systems and deep learning architectures specifically engineered for automated failure detection in visual data.

Students will master critical applications including defect identification in material microstructures and circuit-in-film analysis, working with real-world datasets that mirror current industrial challenges. Under the guidance of an instructor with three decades of hands-on industry expertise, participants will develop proficiency in Google Colab environments and establish robust Python workflows on Linux server architectures—skills that directly translate to professional engineering practice.

The curriculum bridges theoretical foundations with practical implementation, preparing engineers to deploy cutting-edge AI solutions in materials science and manufacturing quality assurance.

Learning outcomes

By the end of the course, students will be able to:

- Apply Python basics and libraries (NumPy, Pandas, Matplotlib, Scikit-Learn) for data exploration and ML workflows.
- Build and evaluate supervised and unsupervised ML models in Colab and on Linux.

- Understand and implement agentic AI systems with dynamic replanning, multi-step tasks, and failure analysis.
- Design and train deep learning models for image-based failure detection in materials science contexts.
- Deploy and experiment with pipelines for automatic defect identification from microstructure or cipher MVC images.

Prerequisites

- Basic programming exposure (any language).
- Engineering or materials science background.
- Access to Google Colab and a Linux server; ability to install Python and common libraries (pip, virtualenv).
- Familiarity with basic probability/statistics is helpful.

Training outline

1. Python & Machine Learning Foundations

Python Programming Essentials

- Variables, data types, control flow, functions, modules in Python
- Using Jupyter notebooks in Google Colab and Linux environments

Data Manipulation & Visualization

- NumPy arrays, Pandas DataFrames, data cleaning & transformation
- Plotting with Matplotlib/Seaborn, exploratory data analysis

Classification & Regression Algorithms

- Linear regression, logistic regression, decision trees, support vector machines, k-nearest neighbors
- Loss functions, regularization, model metrics (accuracy, precision/recall, R^2)

Unsupervised Learning & Feature Engineering

- Clustering (K-means, hierarchical), dimensionality reduction (PCA, t-SNE)

- Feature scaling, encoding, cross-validation, hyperparameter tuning

2. Agentic AI: Autonomous Systems and Intelligent Agents

Introduction to Agentic AI

- Definition: fully autonomous agents making decisions without human intervention
- Comparison to rule-based automation and RPA

Core Components of Agentic Agents

- Memory systems: working, episodic, long-term using vector databases
- Tool interface layer: APIs, file operations, external services
- Dynamic replanning: detect failures, analyse cause, generate alternative strategies

Failure Modes in Agentic AI

- Novel agentic-specific failures: inter-agent communication breakdowns, divergence from task logic
- Classical AI failures: bias, hallucinations, misclassifications

Hands-on: Building an Agent Pipeline in Python

- Set up agent that monitors a process (e.g. file inputs), triggers ML task, adapts when outputs fall below threshold
- Logging, recovery strategies, continuous learning loops

3. Deep Learning for Image-based Failure Detection

Deep Learning Fundamentals

- Overview of convolutional neural networks (CNNs), activations, pooling layers, training loops
- Frameworks: TensorFlow/Keras or PyTorch on Colab/server

Image Preprocessing & Data Augmentation

- Techniques to prepare microscopy or cipher MVC images: normalization, resizing, augmentation (rotation, flipping)

Model Architecture Design

- Standard CNN designs (e.g. simple CNN, ResNet variants), transfer learning from pre-trained models

Training, Validation & Evaluation

- Loss functions for classification/localization, confusion matrices, ROC/AUC metrics
- Techniques to avoid overfitting: regularization, dropout, augmentations, early stopping

Model Explainability & Robustness

- Saliency maps, Grad-CAM, understanding why models succeed/fail
- Adversarial robustness in imaging and detection contexts (relevant to quality control)

Instructor's Experience & Real-World Emphasis

- All content is grounded in **industry-relevant scenarios**: inspection of materials, failure prediction, automated quality control.
- Hands-on labs and examples drawn from real datasets used in aerospace, semiconductor, and materials processing.
- Emphasis on **practical pipelines**—from data acquisition through deployment—with reproducible code across Colab and Linux.
- No academic fluff: you get tools, solutions, and workflows that matter in today's engineering environments.

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