

MLOps Engineering

Machine Learning Operations V2.0.0

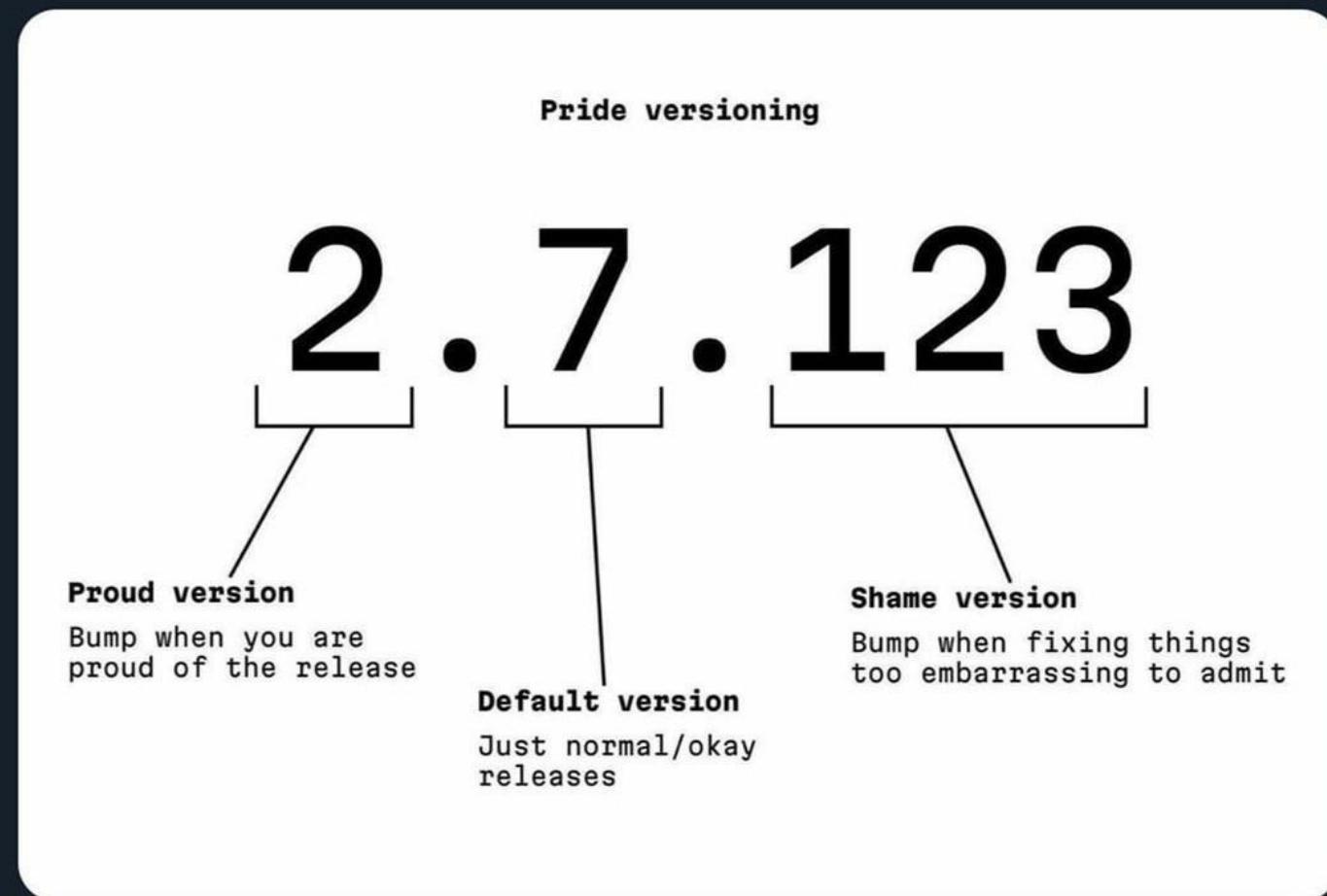
Sessions 1 - 2

MsC in Business Analytics and Data Science

Madrid, May 2025



in case you didn't know, this is how you're actually supposed to do software versioning



Semantic Versioning

Agenda

- **Your facilitator**
- **Course intro/ admin**
- **Logistics**
- **MLOps 101**

You Facilitator



Ivan Diaz
PhD Student





Modern Data Architectures – Approach to Data Lakes



Key Vault (credential and secret management)



Azure Logic Apps
Logic Apps (business workflows)

Data Sources

Internal (primary sales, supply chain, finance, master data)



ORACLE



External (secondary sales, marketing [brand equity, panel], weather)

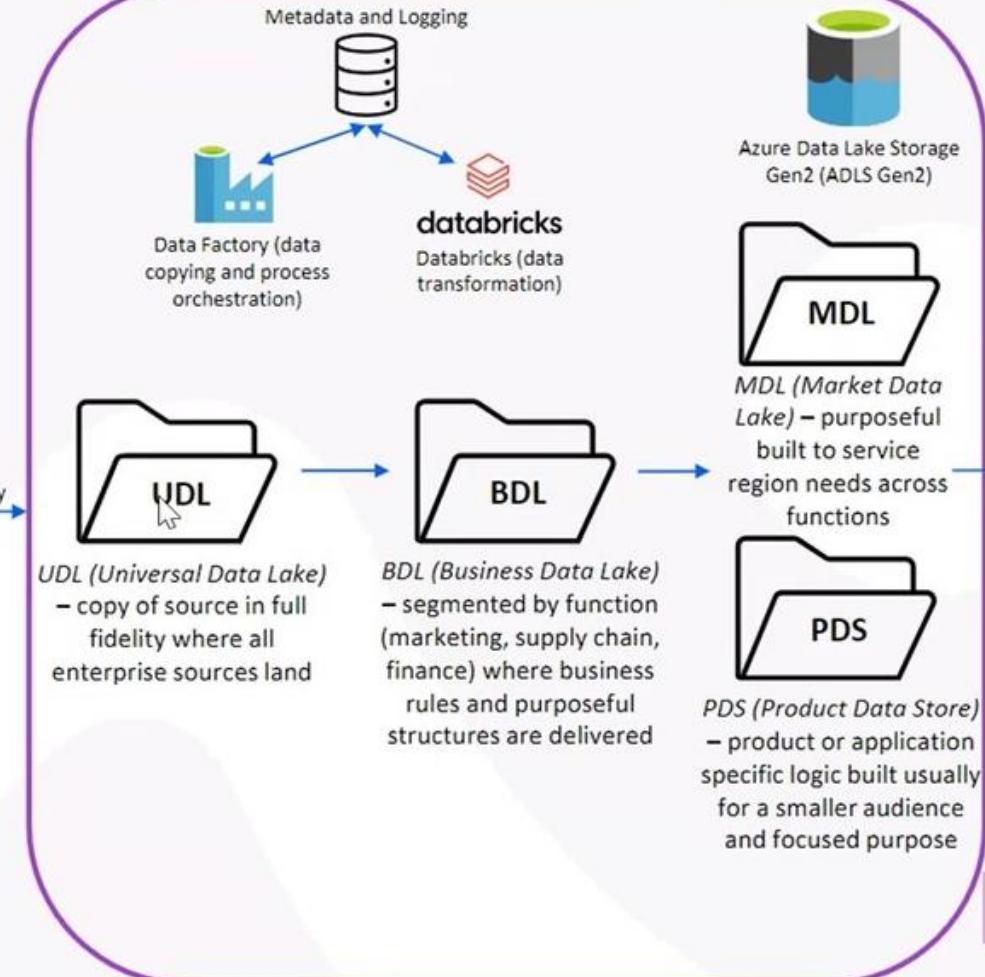


FTP



CANTAR MillWARDBROWN

File-Based Repository “Data Lake”



Semantic



Azure SQL Database



Azure Synapse Analytics "SQL Pool" (prev. SQL DW – MPP data warehouse)



Databricks SQL

Reporting



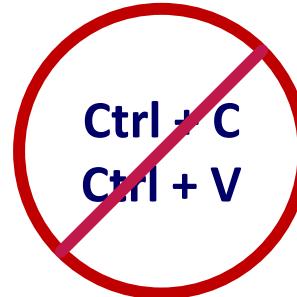
Azure Analysis Services



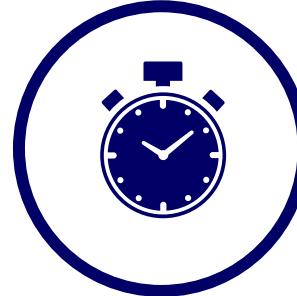
Microsoft Power BI

Let's align on our rules of engagement...

DON'T



DO



Let's review some
common
misconceptions...



1



2



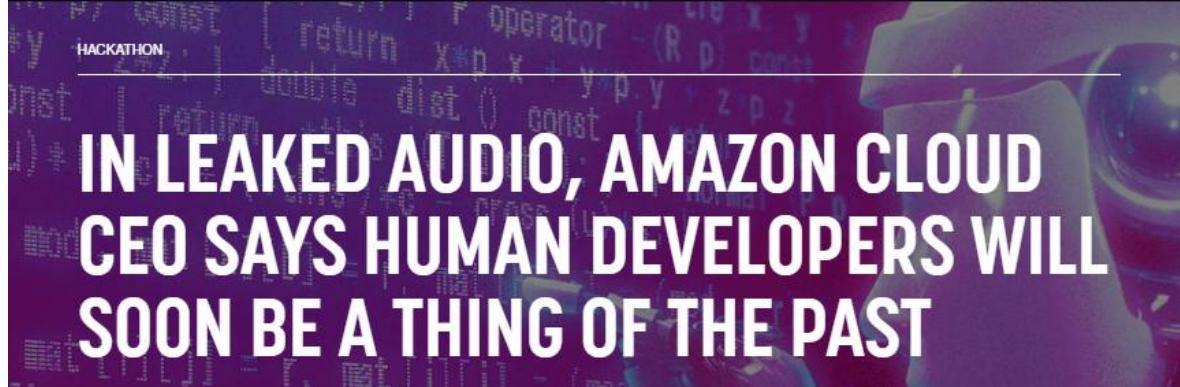
When you think about
Software Engineering,
what images come to
mind?

2



Technical skills are still essential to stay competitive in today's fast-changing environment

3



Software Apps > Work Productivity

Amazon cloud boss echoes NVIDIA CEO's of coding being dead in the water with the rapid prevalence of AI sentiments: "If you go forward 24 months from now, it's possible that most developers are not coding"

News

By Kevin Okemwa published yesterday

Software Apps

NVIDIA CEO says the future of coding as a career might already be dead in the water with the imminent prevalence of AI

News By Kevin Okemwa published February 28, 2024

Generative AI could claim more jobs in the tech landscape, rendering coding professionals redundant.

Stability AI CEO: There Will Be No (Human) Programmers in Five Years

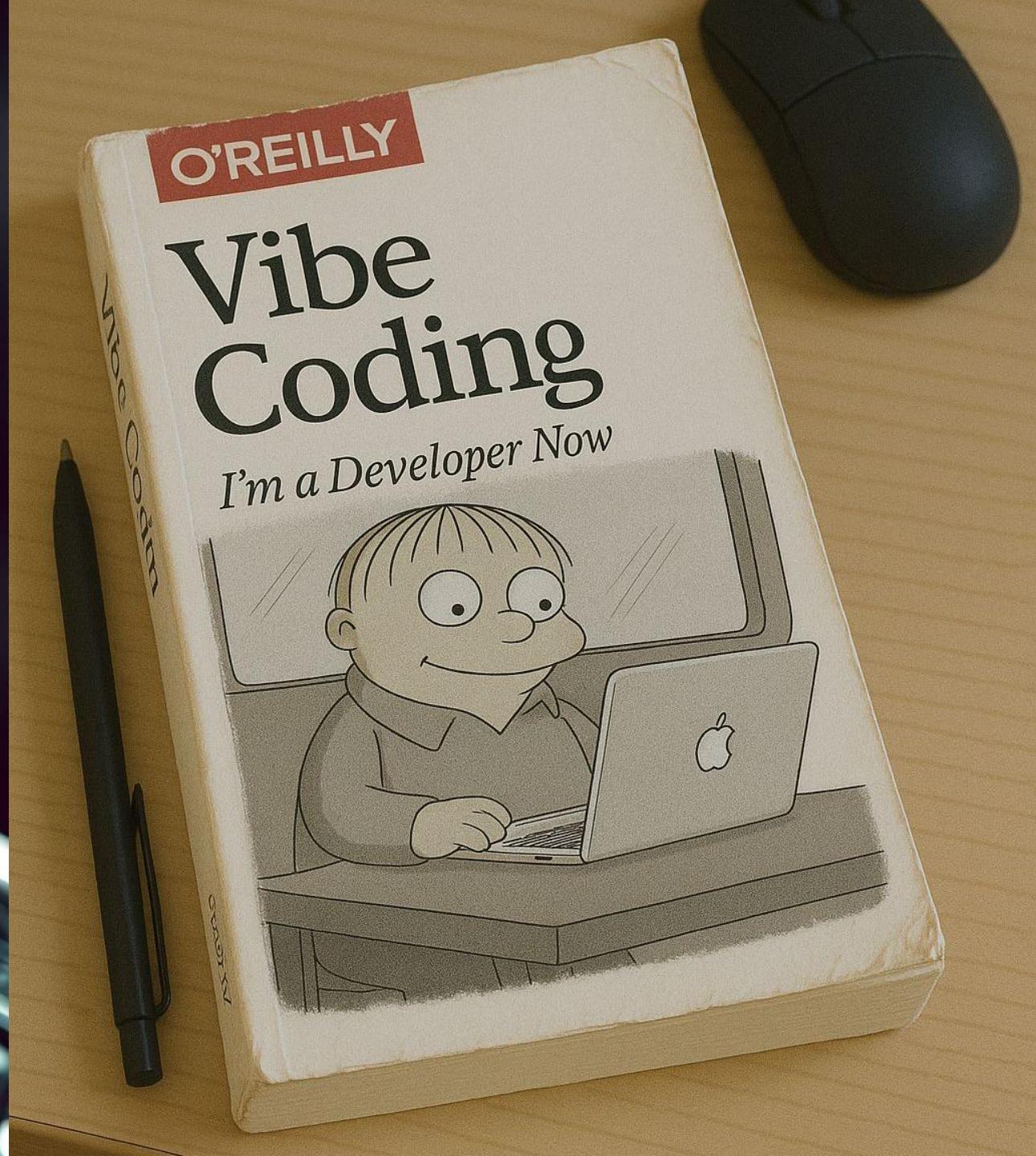
Many believe AI will bring the end of the world, but Emad Mostaque believes AI (and humans) can change it.



Source: Image from Bing Image creator; ; [Independent](#)



Source: Image from Bing Image creator; ; [Independent](#)

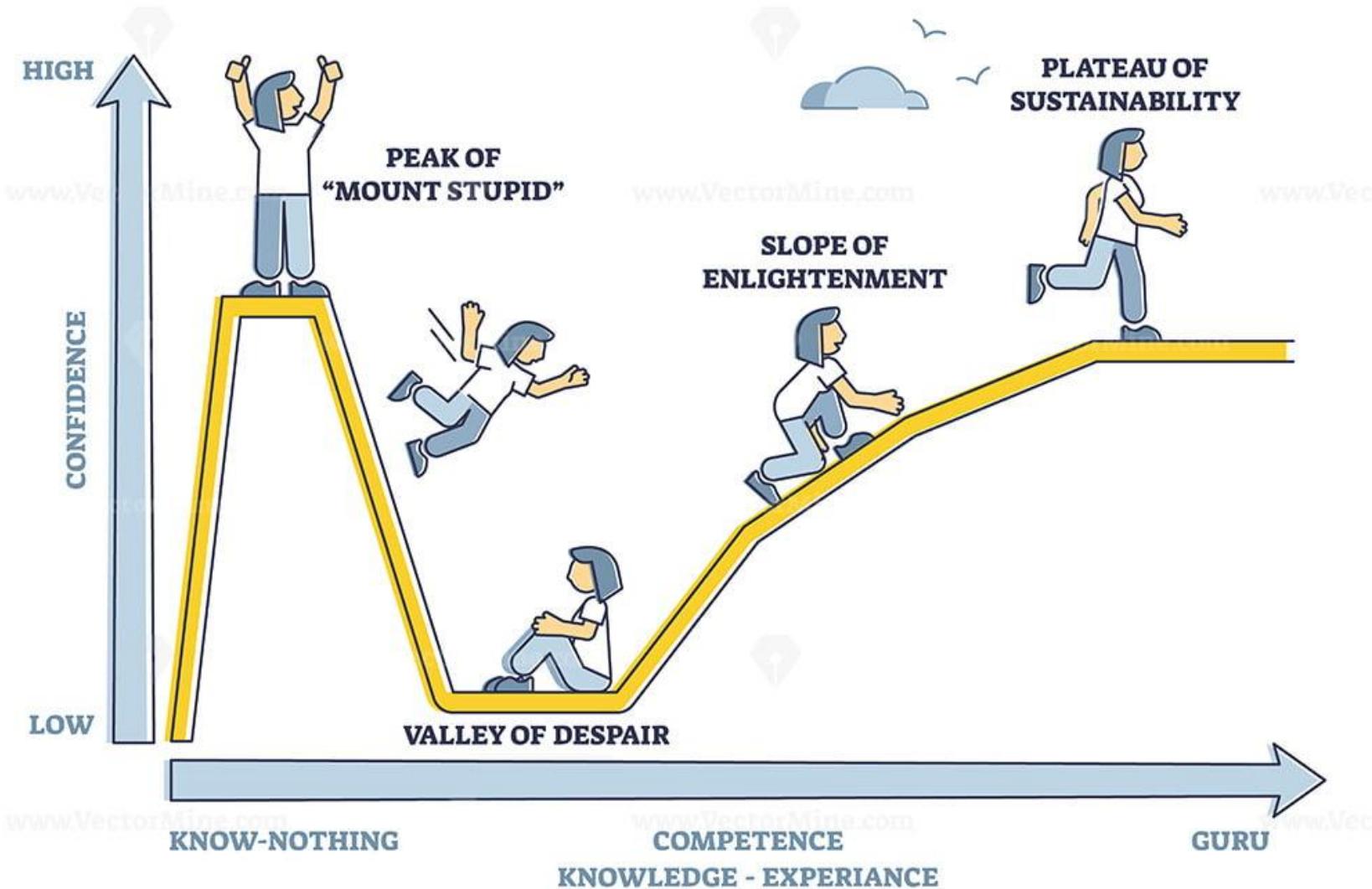


What the course is **NOT** intended to be...

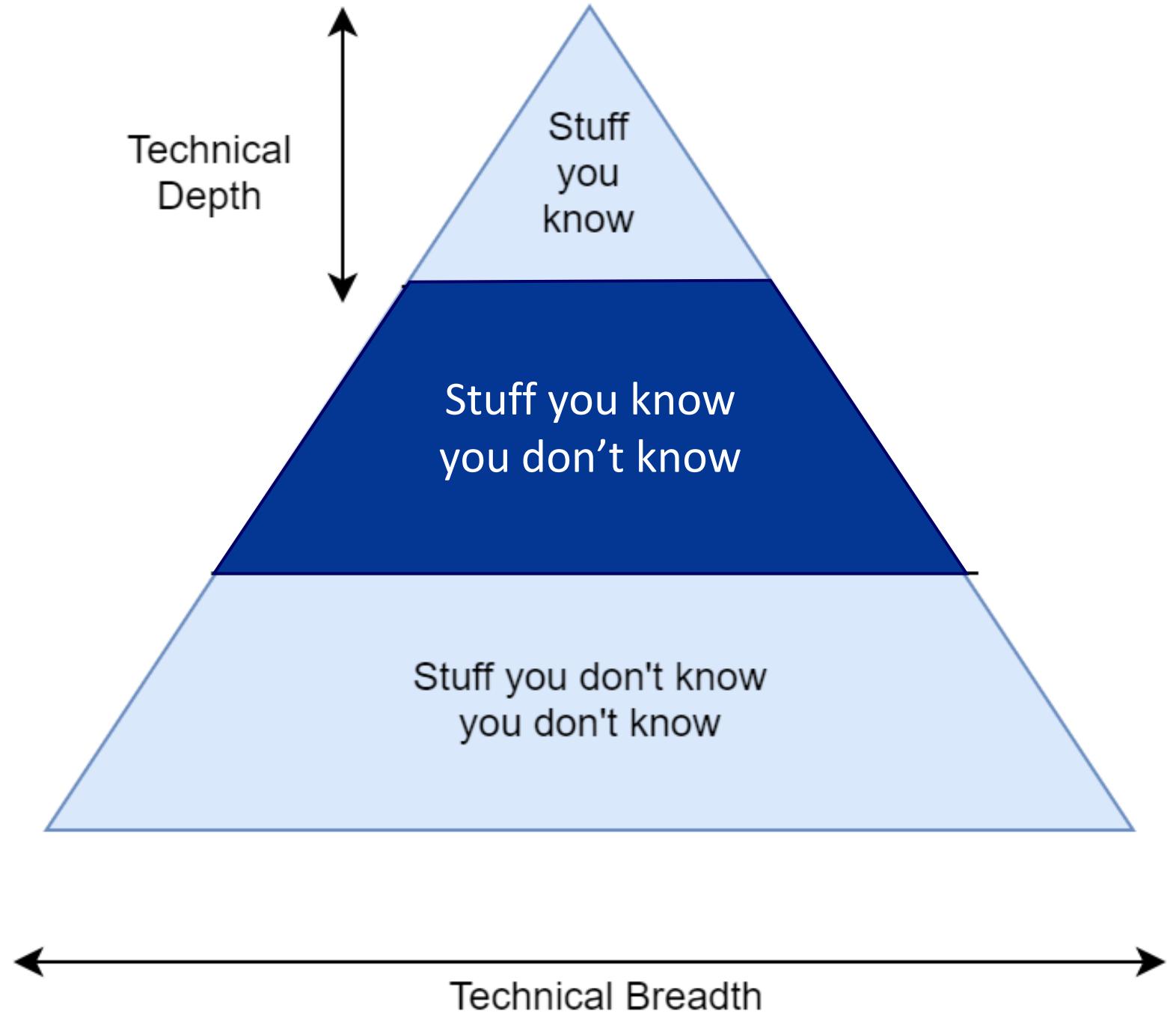
- 1 A programming/ scripting course (Python, YALM, MLflow, Bash, etc.)
- 2 Online debugging & troubleshooting sessions (MS Teams)
- 3 A WebApp/ Full Stack dev course
- 4 “Yet Another” ML/ AI course

***“People with
low ability at a
task
overestimate
their ability”***

DUNNING KRUGER EFFECT

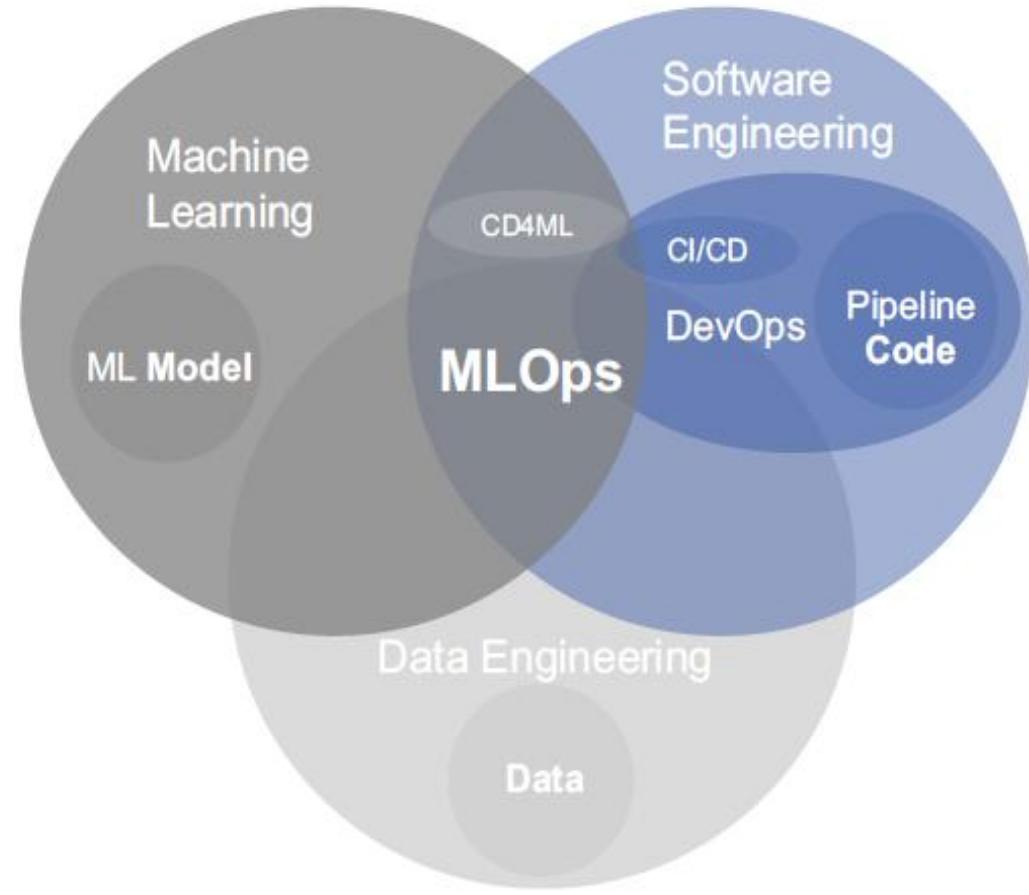


**Today, more
than ever, it's
critical for you
to increase
your technical
breadth!**



We borrow from modern SWE principles, to move ML into successful production

1. CI/CD automation
2. Workflow orchestration (DAG)
3. Reproducibility
4. Versioning of data, code, model
5. Collaboration
6. Continuous ML training & evaluation (CT/ CM)
7. ML metadata tracking
8. Continuous monitoring
9. Feedback loops



Important changes to your previous Syllabus!

SUBJECT DESCRIPTION

In Machine Learning Operations (MLOps) we focus on streamlining the process of taking machine learning models to production, and then maintaining and monitoring them.

Embark on this transformative journey into MLOps, where we will discuss all the steps in a complete machine learning process. Through comprehensive theoretical lectures and practical tools demonstrations, you will gain the understanding of the challenges necessary to navigate the complex landscape of models in production.

AI POLICY

Restricted use of GenAI

In today's world, generative artificial intelligence (GenAI) is changing how we work, study and, in general, how we get things done. However, in the context of this course, the use of GenAI is not permitted, unless it is otherwise stated by the instructor. The use of GenAI tools would jeopardize the students' ability to acquire fundamental knowledge or skills of this course.

If a student is found to have used AI-generated content for any form of assessment, it will be considered academic misconduct, and the student might fail the respective assignment or the course.

By aligning machine learning initiatives with business objectives and regulatory requirements, an MLOps plan will assure a successful machine learning deployment driving value creation and competitive advantage.

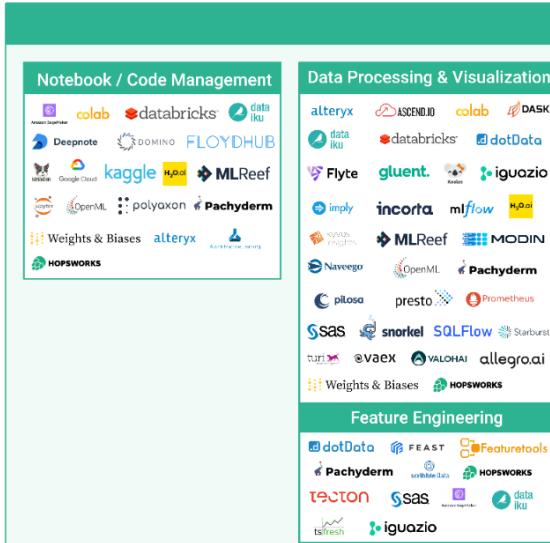
No!! Is about taking a business idea and ensuring it **realises business value!**

Much less “comprehensive theoretical lectures” and “tool demos”! **You’ll learn by doing!**

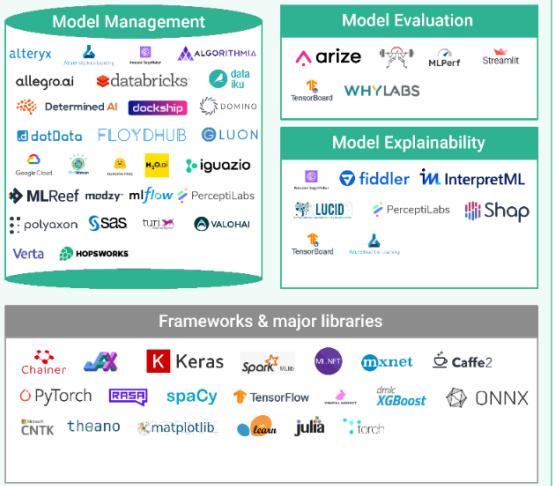
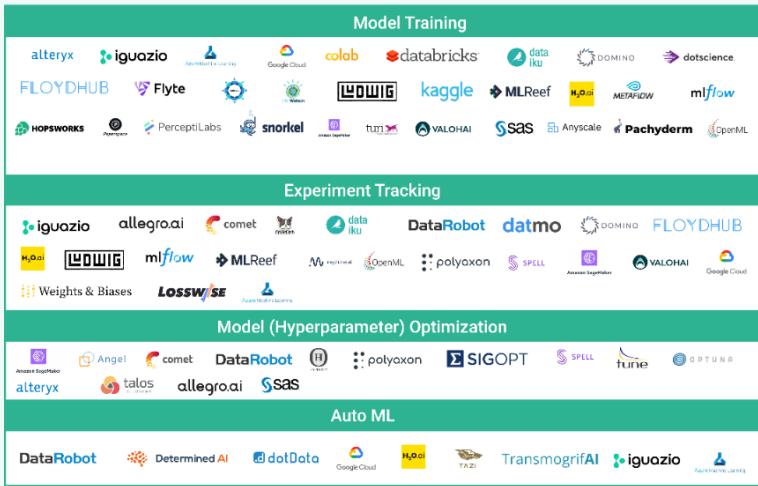
Seriously??

There’s no ML initiatives w/ out business objectives

DATA MANAGEMENT



MODELLING



CONTINUOUS DEPLOYMENT



COMPUTING MANAGEMENT

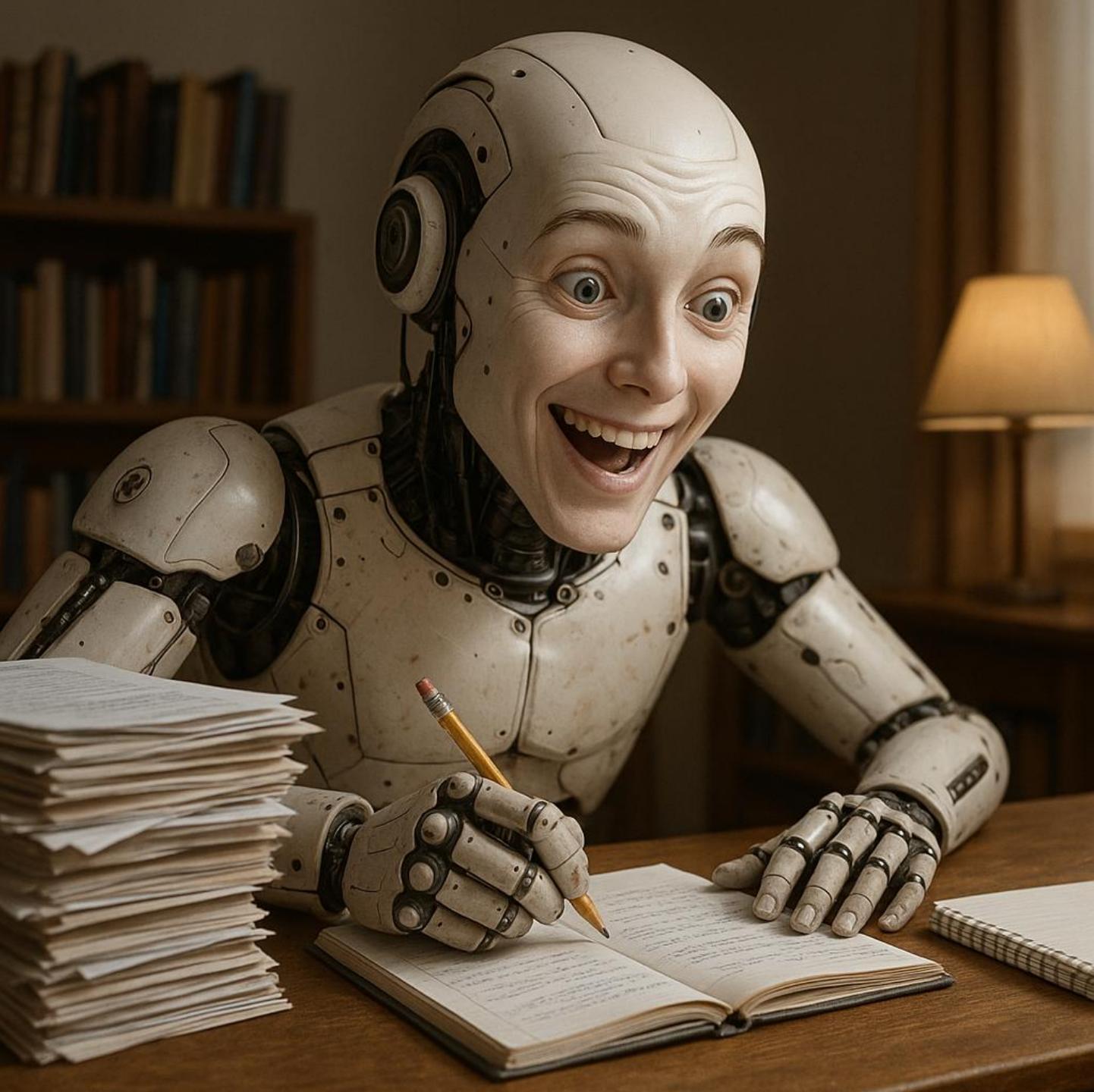


Source: mlreef

Our working Tech Stack

	This course	Others
Code tracking, VS, CI/CD	GitHub, Actions	GitLab, Bitbucket, Jenkins
Experiment, Artifact and model tracking	Weights & Biases	MLflow, Neptune...
ML pipelines, Orchestration, and monitoring	MLflow + Hydra	Kubeflow, TFX, K8s, Azure, AWS, GCP Grafana
Environment isolation	Conda	Docker
Modeling/ Serving	Scikit-learn, FastAPI	TensorFlow (Keras), PyTorch (Fast.ai)
Data versioning	DVC	LakeFS, Azure, AWS, GCP

Assignments and grades



Evaluation methodology

Class Participation: **0.0**

Final exam fail: **3.5/10.0**

Activity	Weight	Description	(Tentative) Deadline
Ind. Class participation	20%	0 Relevant contributions in class and/ or via Teams	ON GOING
1st Group Presentation	15%	1 1st group deliverable (Business case, VC'ed, production-ready-code)	SESSION 8 (29 st May)
Intermediate test	10%	2 Initial core concepts & fundamental best practices	SESSION 9 (29 th May)
2 nd Group Work	25%	3 Final group project (End-to-end CI/CD)	SESSION 14 (25 th Jun)
Ind. Final Exam	30%	4 Final closed-book exam	SESSIONS 15 (25 th Jun)
Total	100%		

A project wrongly scoped, is a project set up for failure



- Define clear business **objectives** and how the model will contribute
- Define the problem in **ML terms**
- Identify key **stakeholders** and their respective roles
- Decide on crucial **performance metrics**: accuracy, latency, throughput, etc.
- Understand resource allocation including **budget, manpower, and technology**
- Set a realistic **project timeline** considering potential challenges and delays

Let's apply these principles to a Data Scientist generated notebook!

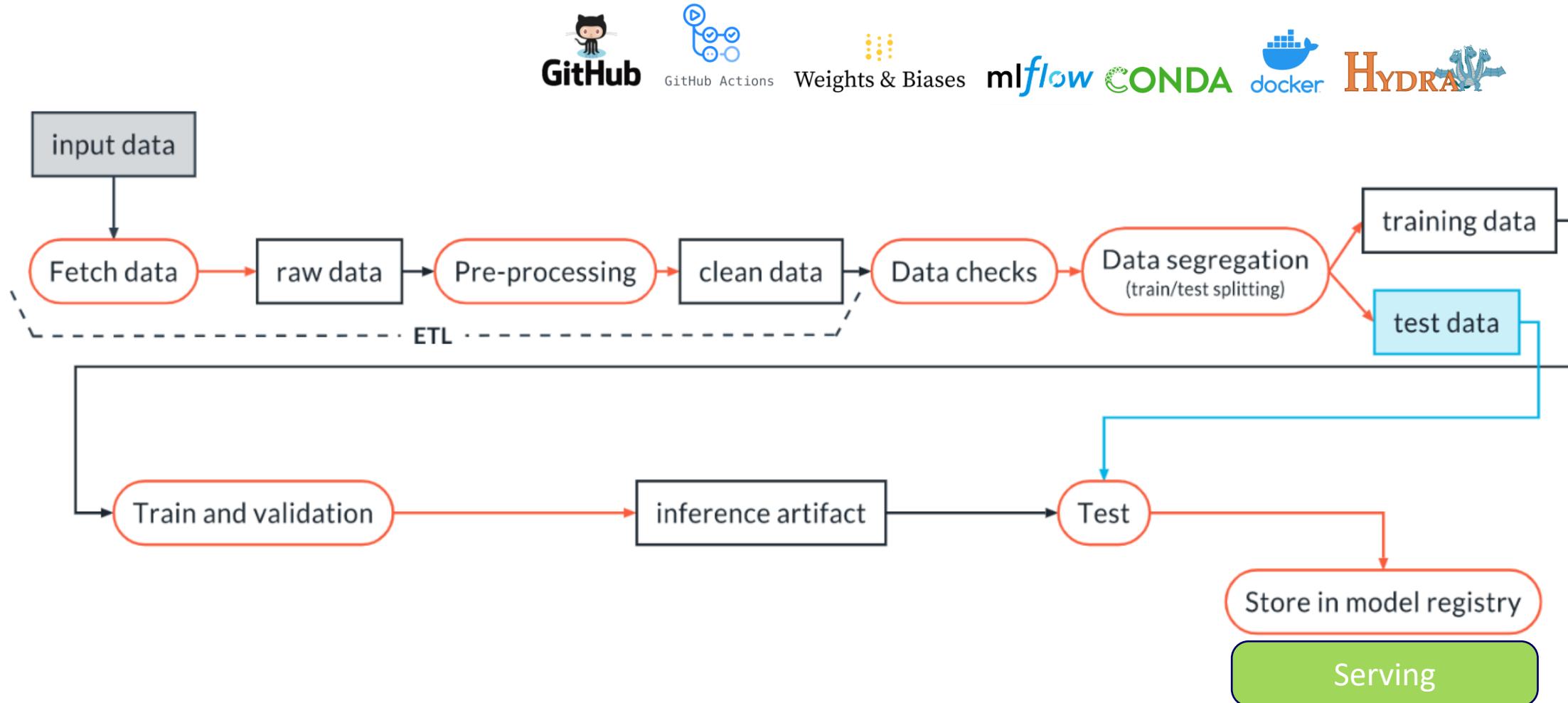
General best practices

1. **Modularization:** Break down code into smaller, reusable functions or classes.
2. **Configuration Management:** Use configuration files or environment variables for settings.
3. **Logging and Monitoring:** Add logging and possibly some basic monitoring metrics.
4. **Error Handling:** Include comprehensive error handling and data validation.
5. **Dependency Management:** List all dependencies and versions for reproducibility.
6. **Documentation:** Include sufficient comments and documentation for maintainability.
7. **Code Quality:** Ensure the code is clean, readable, and follows PEP 8 standards.
8. **Testing:** Include unit tests to validate the functionality.

ML Pipeline specific

1. **Data Loading:** Create a function to load the data.
2. **Data Exploration:** Modularize the code used for data exploration into reusable functions.
3. **Data Preprocessing:** Create functions for preprocessing steps like handling missing values, scaling, etc.
4. **Feature Engineering:** If applicable, create functions for feature engineering.
5. **Model Training:** Create functions for training machine learning models.
6. **Evaluation:** Create functions for model evaluation.
7. **Utility Functions:** Create utility functions for common operations like plotting.

Following production-ready best practices, we'll build and deploy an e2e ML solution



Tools and resources



Where are we?

- Python – Production ready code?
- Git, Github & GitFlow
- Terminal/ Bash commands
- IDEs (Different to Notebooks)
- Testing & Logging
- Scikit-learn pipelines

Tools & Environment checklist

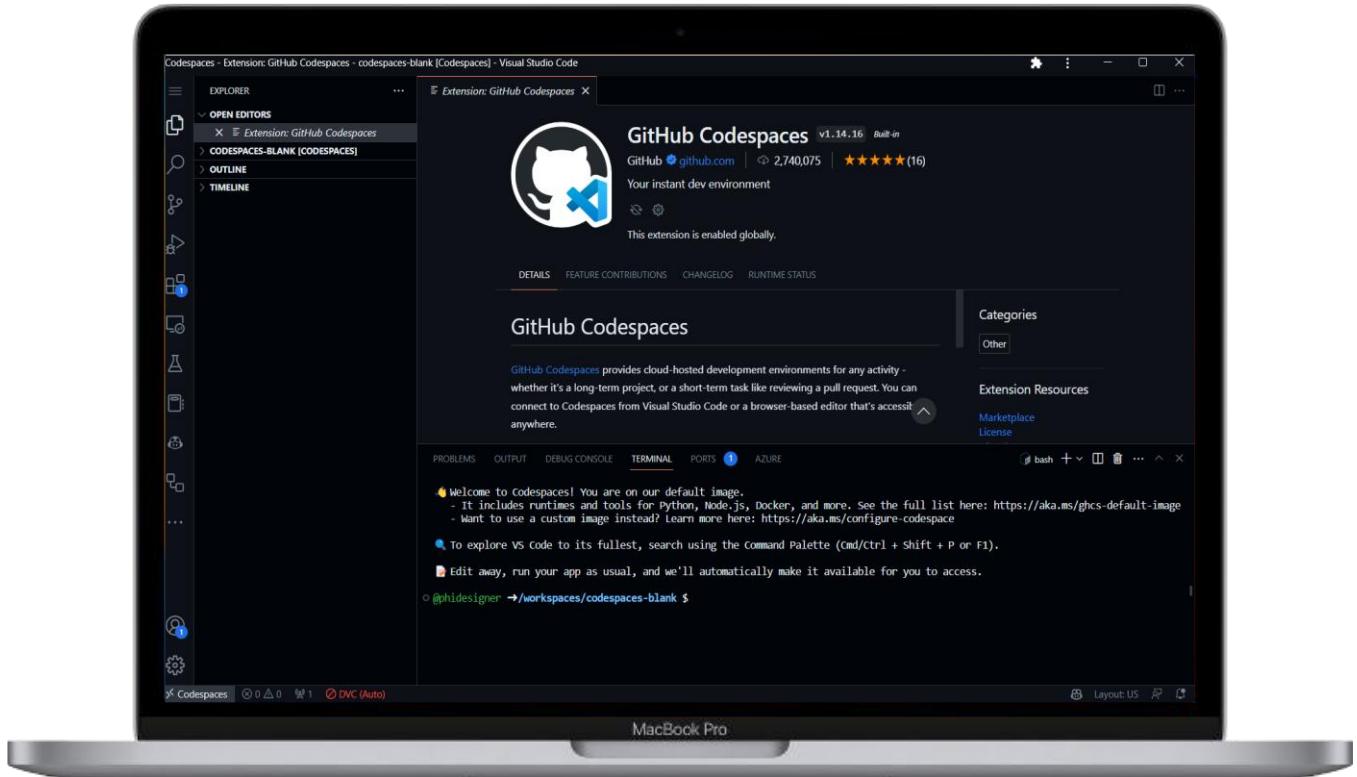
- **Libraries:**
 - Python 3.8+
 - Miniconda
 - Git
 - GitHub account
- **Software:**
 - Visual Studio Code (IDE)
 - Git Bash (Windows)
 - WSL for windows
- **Accounts (Student):**
 - Copilot
 - Weights & Biases
 - GitHub Codespaces
 - MS Teams
 - ChatGPT+ or Cursor (Optional)
- **Jupyter/ ML model of your choice**

Our Teams Group



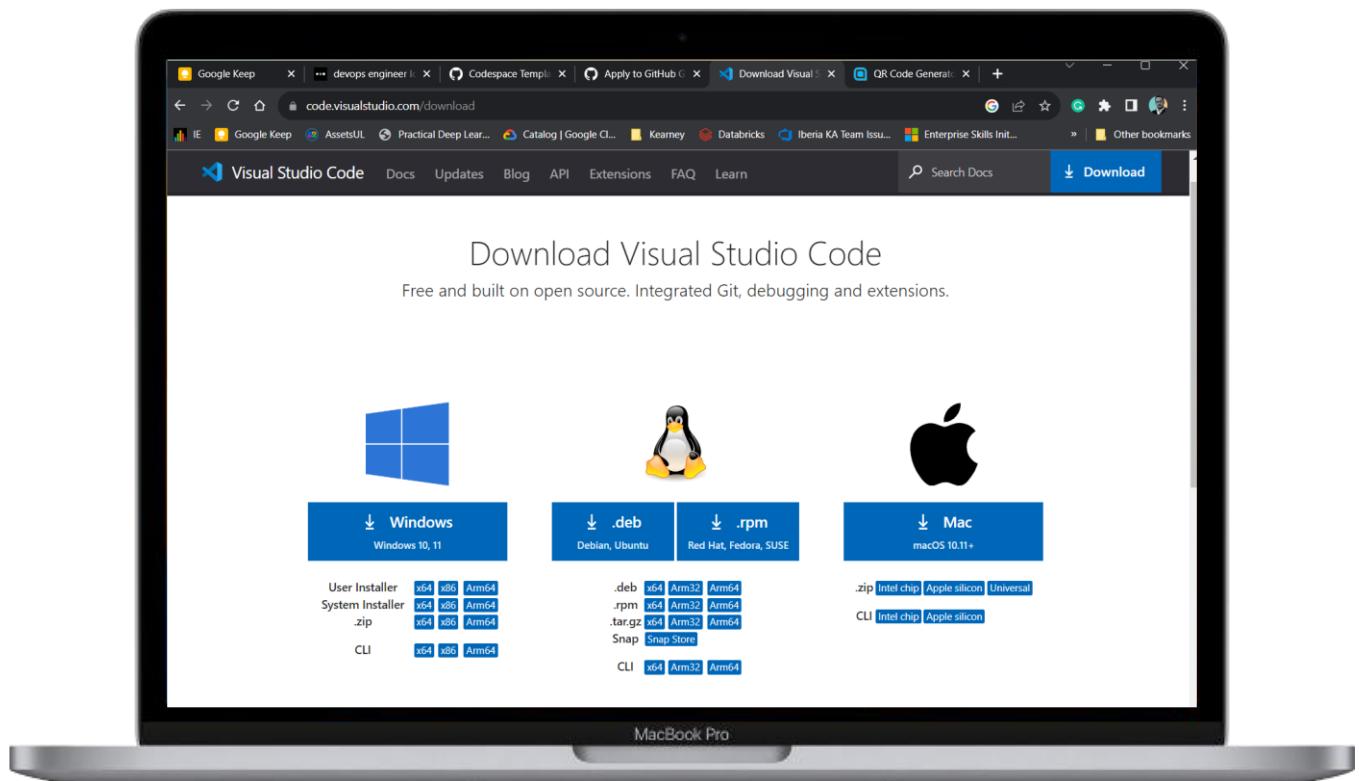
[MLOps Teams' link](#)

GitHub Codespaces



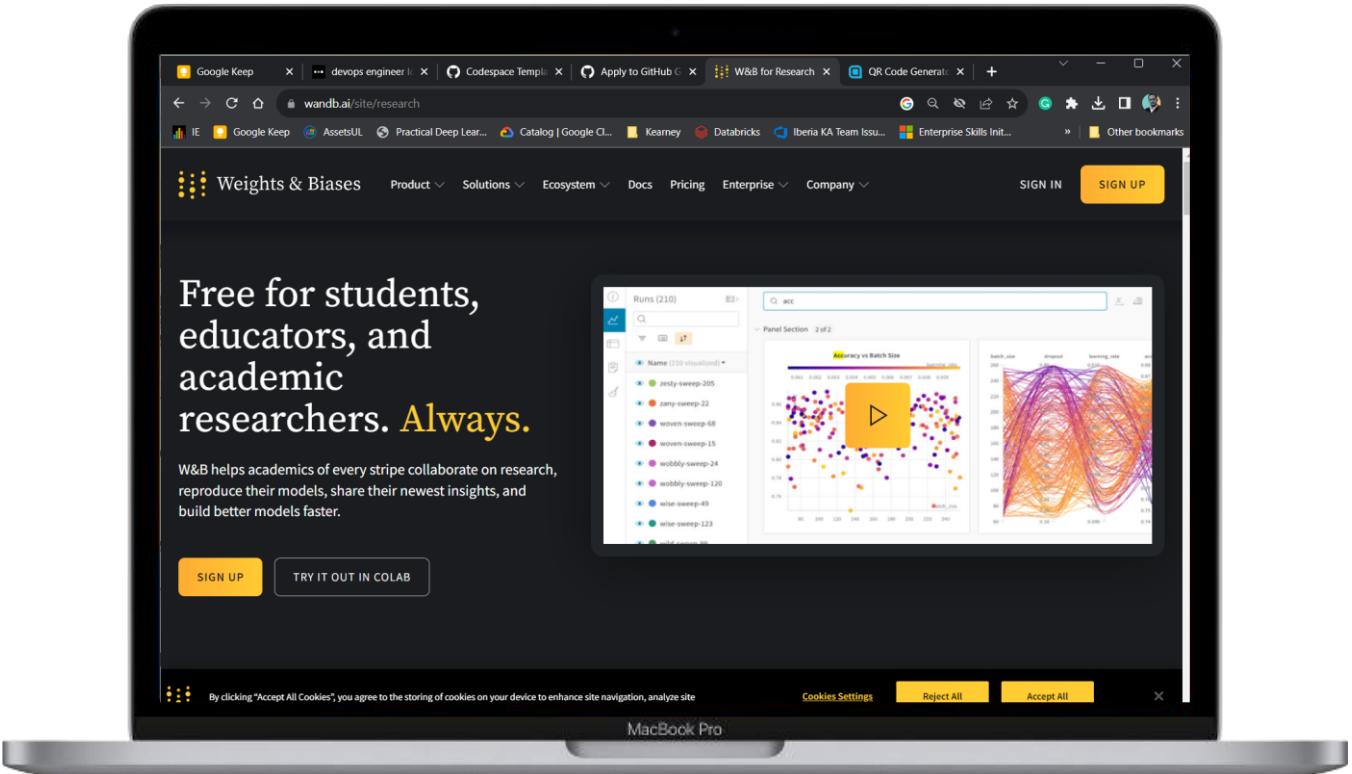
[GitHub Codespaces](#)

Visual Studio Code



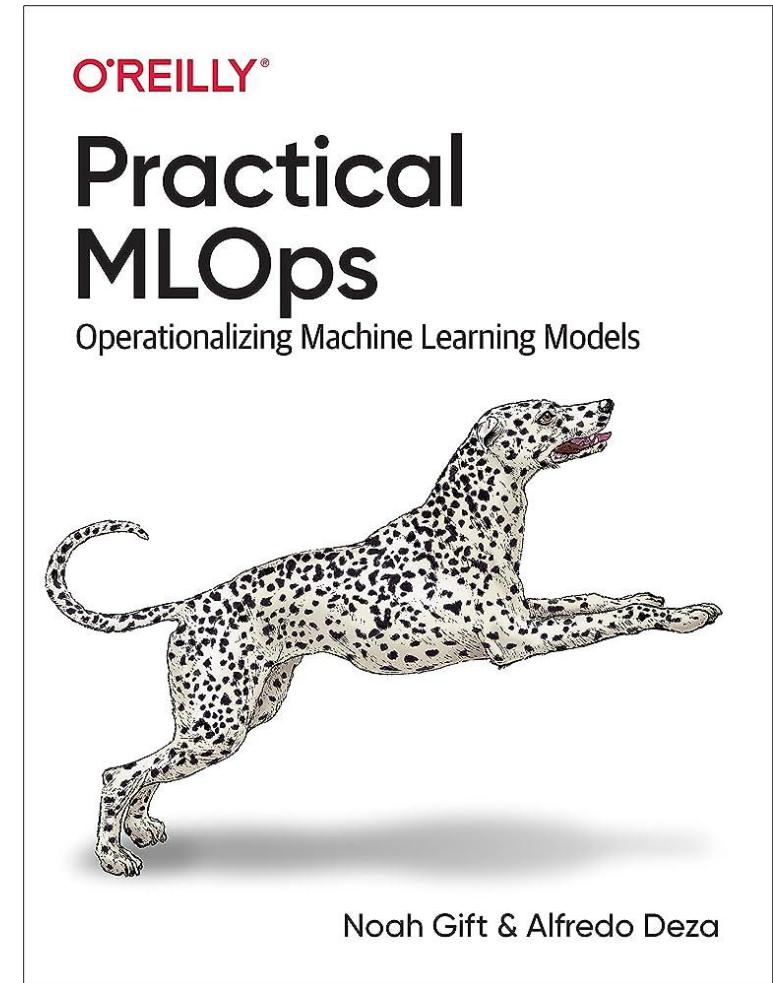
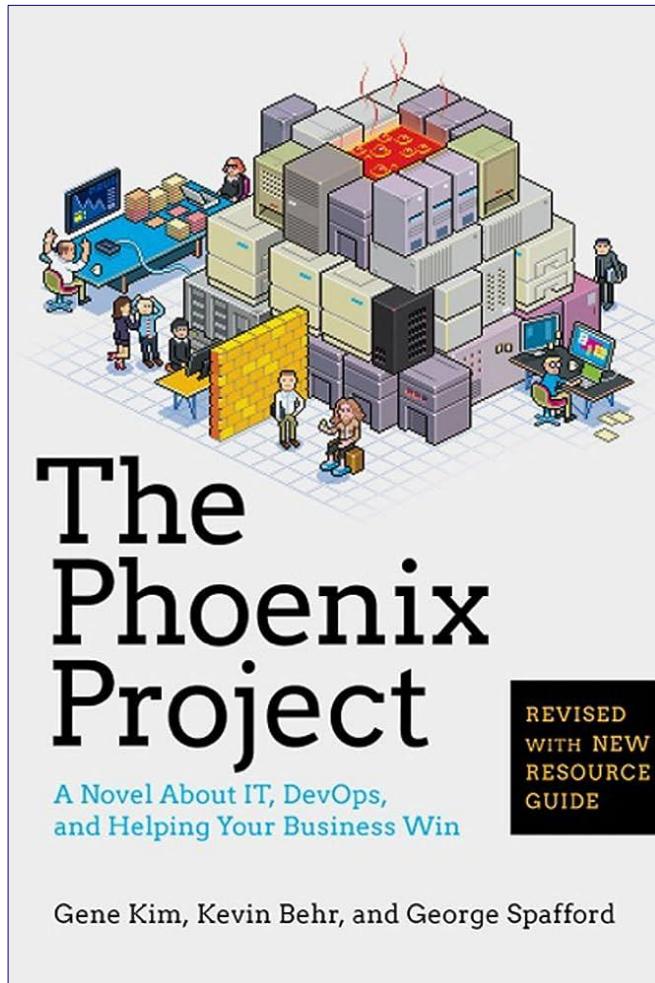
[Visual Studio Code](#)

Weights and Biases

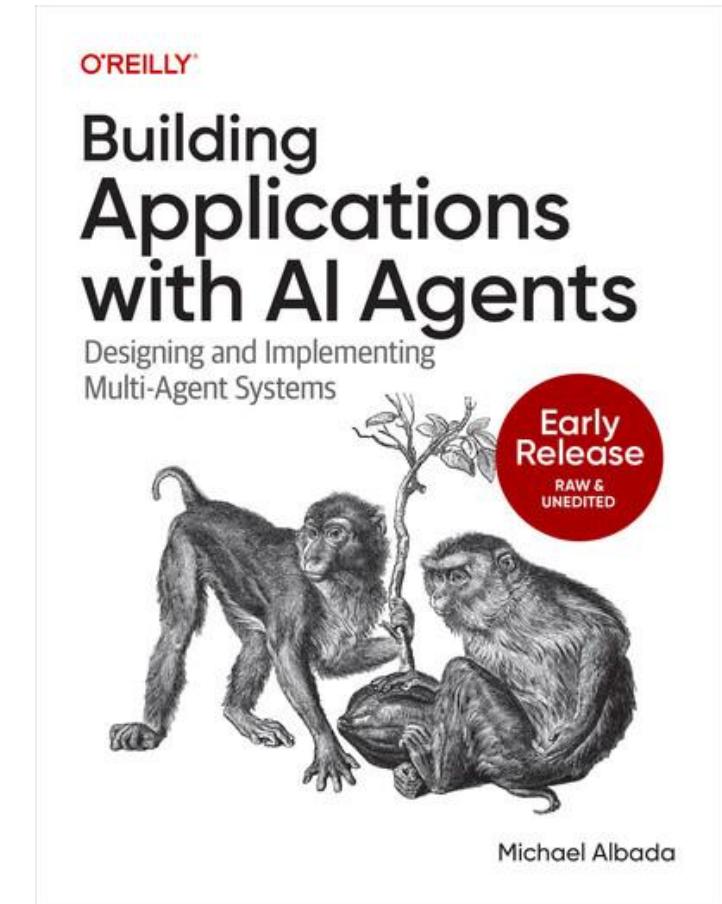
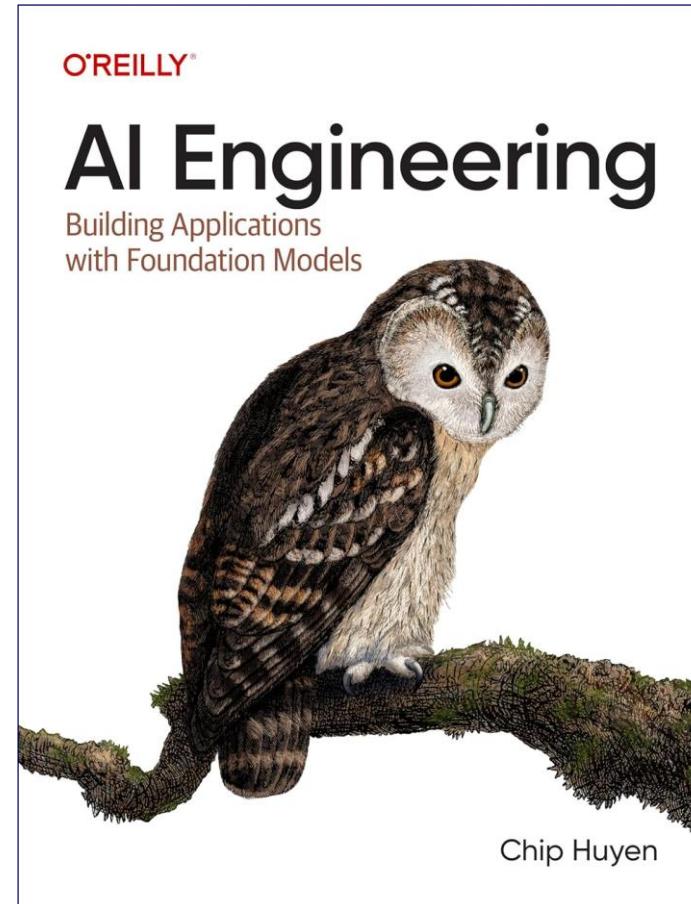
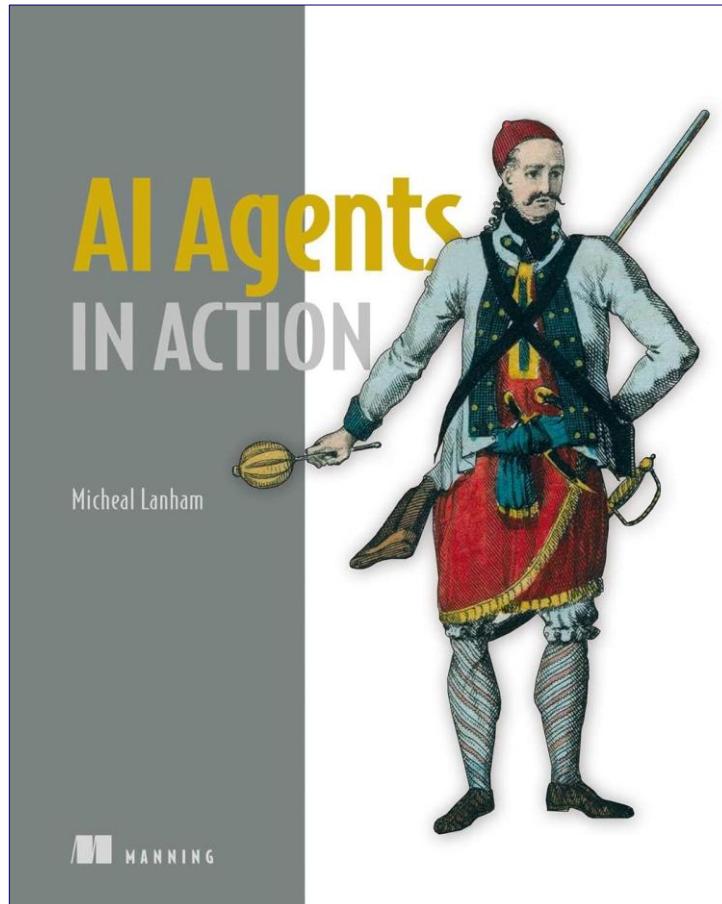


[WandB](#)

Must reads...



Next on your bed side table...



Optional: Introduction to Git and GitHub

The screenshot shows a Coursera course page for "Introduction to Git and GitHub" by Google. The page includes the course title, instructor information, enrollment options, and a summary box with course details.

Course Title: Introduction to Git and GitHub

Instructor: Google Career Certificates (Top Instructor)

Enrollment: Enroll for Free (Starts Aug 29) | Financial aid available

Course Summary:

- Course:** Gain insight into a topic and learn the fundamentals
- Rating:** 4.8 ★ (6,885 reviews) | 97%
- Level:** Beginner level | No previous experience necessary
- Duration:** 16 hours (approximately)
- Schedule:** Flexible schedule | Learn at your own pace

Statistics: 232,012 already enrolled

Navigation: About, Outcomes, Modules, Recommendations, Testimonials, Reviews

Audit the course, you won't need to pay for it!

7-day Free Trial

Introduction to Git and GitHub is part of the larger Google IT Automation with Python Professional Certificate. Your 7-day free trial includes:

- ✓ **Unlimited access to all courses in the Certificate**
Watch lectures, try assignments, participate in discussion forums, and more.
- ✓ **Cancel anytime.**
No penalties - simply cancel before the trial ends if it's not right for you.
- ✓ **€45 per month to continue learning after trial ends.**
Go as fast as you can - the faster you go, the more you save.
- ✓ **Certificate when you complete.**
Share on your resume, LinkedIn, and CV.

[Start Free Trial](#)

[Audit the course](#)

Optional: Introduction to GitHub Actions

The screenshot shows a Microsoft Edge browser window with a dark theme. The address bar displays the URL: learn.microsoft.com/en-us/training/patterns/automate-workflow-github-actions/. The Microsoft Learn header includes links for Documentation, Training (which is underlined), Certifications, Q&A, Code Samples, Assessments, Shows, Events, a Search bar, and Sign in. Below the header, the navigation menu shows Training selected, along with Products, Career Paths, Learning Paths, Courses, Educator Center, Student Hub, and FAQ & Help. The breadcrumb trail indicates the user is at Learn / Training / Browse /. The main content area features a blue diamond icon with a white gear and arrows, followed by the title "Automate your workflow with GitHub Actions". Below the title, it says "5 hr 13 min • Learning Path • 6 Modules" and lists skill levels: Beginner, Intermediate, DevOps Engineer, Administrator, Developer, Solution Architect, GitHub, and Azure. A brief description states: "Learn how GitHub Actions enables you to automate your software development cycle and deploy applications to Azure." Under "In this learning path, you'll:", there is a bulleted list:

- Plan automation of your software development life cycle with GitHub Actions workflows.
- Use GitHub Actions to automatically build your application.
- Deploy to Microsoft Azure with GitHub Actions.
- Use GitHub Script to interact with the GitHub API.

Excellent online resources (Spotify, Audible, YouTube)



<https://podcast.mlops.community/>

The screenshot shows the homepage of The MLOps Podcast. At the top right, there are links for "Community", "Recent Episodes", and "Listen Now". Below that, the title "The MLOps Podcast" is prominently displayed in a large, bold, white font. A subtitle explains the content: "Weekly talks and fireside chats about everything that has to do with getting Machine Learning going in the **real** world." A pink button at the bottom encourages users to "Listen now on Apple Podcasts" with a headphones icon. Below the button are icons for Spotify, Apple Podcasts, and RSS feed.

<https://github.com/visenger/awesome-mlops>

Excellent online resources (free)



Table of Contents

MLOps Core	MLOps Communities
MLOps Books	MLOps Articles
MLOps Workflow Management	MLOps: Feature Stores
MLOps: Data Engineering (DataOps)	MLOps: Model Deployment and Serving
MLOps: Testing, Monitoring and Maintenance	MLOps: Infrastructure
MLOps Papers	Talks About MLOps
Existing ML Systems	Machine Learning
Software Engineering	Product Management for ML/AI
The Economics of ML/AI	Model Governance, Ethics, Responsible AI
MLOps: People & Processes	Newsletters About MLOps, Machine Learning, Data Science and Co.

Excellent online resources (free)



<https://madewithml.com/#course>

ML for Developers

Design · Develop · Deploy · Iterate

Learn how to combine machine learning with software engineering to design, develop, deploy and iterate on production ML applications. → [GokuMohandas/Made-With-ML](#)

1. 🎨 Design

- Setup
- Product
- Systems

2. 📊 Data

- Preparation
- Exploration
- Preprocessing
- Distributed

3. 🤖 Model

- Training
- Tracking
- Tuning
- Evaluation
- Serving

4. 💻 Develop

- Scripting
- Command-line

5. 📁 Utilities

- Logging
- Documentation
- Styling
- Pre-commit

6. 🧪 Test

- Code
- Data
- Models

7. 🔄 Reproducibility

- Versioning

8. 🚀 Production

- Jobs & Services
- CI/CD workflows
- Monitoring
- Data engineering

💡 Live cohort

Sign up for our upcoming live cohort, where we'll provide **live lessons + QA, compute (GPUs) and community** to learn everything in one day.

[Learn more](#)

Excellent online resources (Paid)



<https://www.deeplearning.ai/courses/machine-learning-engineering-for-production-mlops/>

DeepLearning.AI

Courses ▾ The Batch ▾ Blog ▾ Events ▾ Resources Company ▾ Get AI News

Courses > Machine Learning Engineering for Production (MLOps) Specialization

Overview Syllabus Instructors FAQs Enroll Now

COURSE

Machine Learning Engineering for Production (MLOps) Specialization



DeepLearning.AI

Andrew Ng, Cristian Bartolomé Arámburu, Robert Crowe, Laurence Moroney

4 Courses

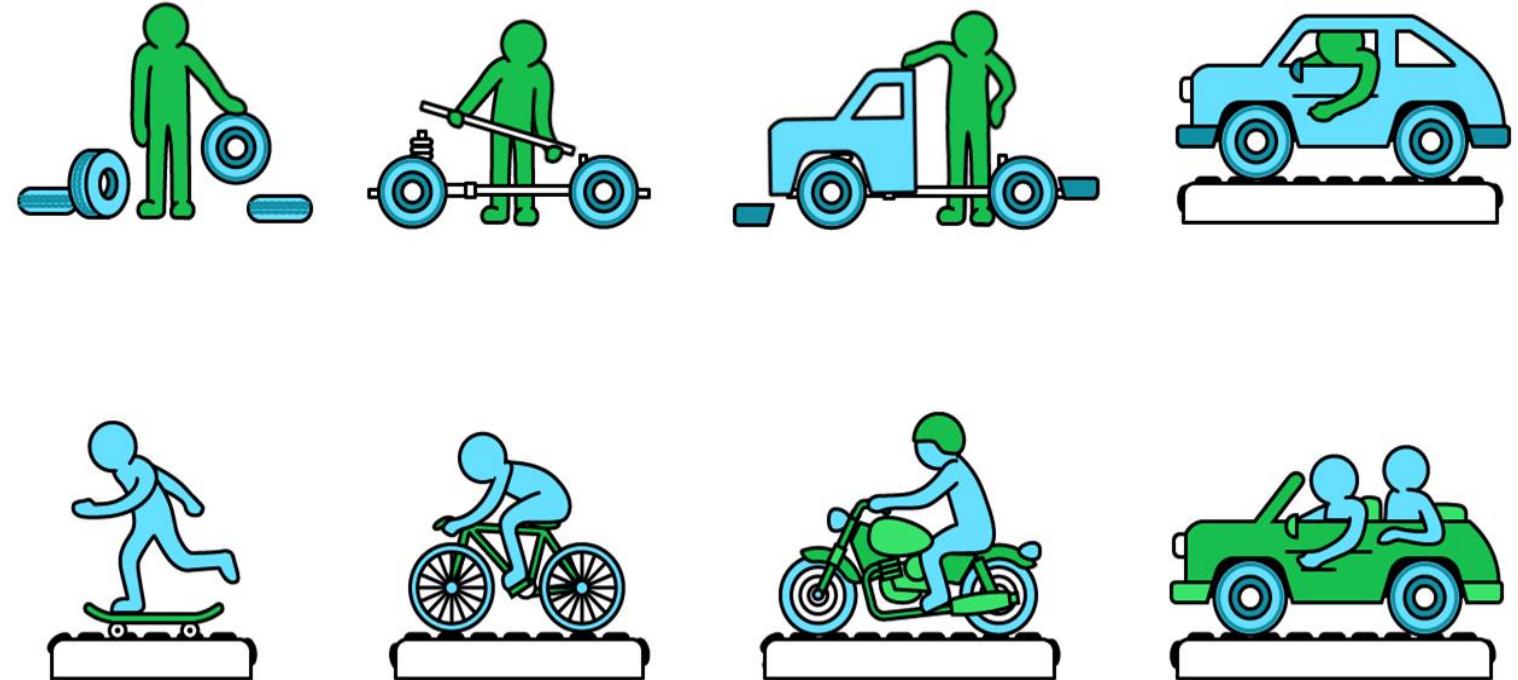
Advanced

4 months (5 hours/week)

Enroll Now

A screenshot of the DeepLearning.AI website showing the "Machine Learning Engineering for Production (MLOps) Specialization". The page includes the course title, a video thumbnail of Andrew Ng speaking, and course details such as the number of courses, level, duration, and instructors. A prominent red "Enroll Now" button is at the bottom right.

*“In Scrum, we **embrace change** because we understand that it’s an **essential part of progress**. Instead of resisting change, let’s learn to dance with it!” – John Agileston*



What's
MLOps
anyways?



“~80%+ of all Machine Learning models never make it into production”

... Said everyone in industry

10%

ML/ AI Models

20%

Configuration

Data Collection

Data Verification

Machine resource
Mgt.

Servicing Infrastructure

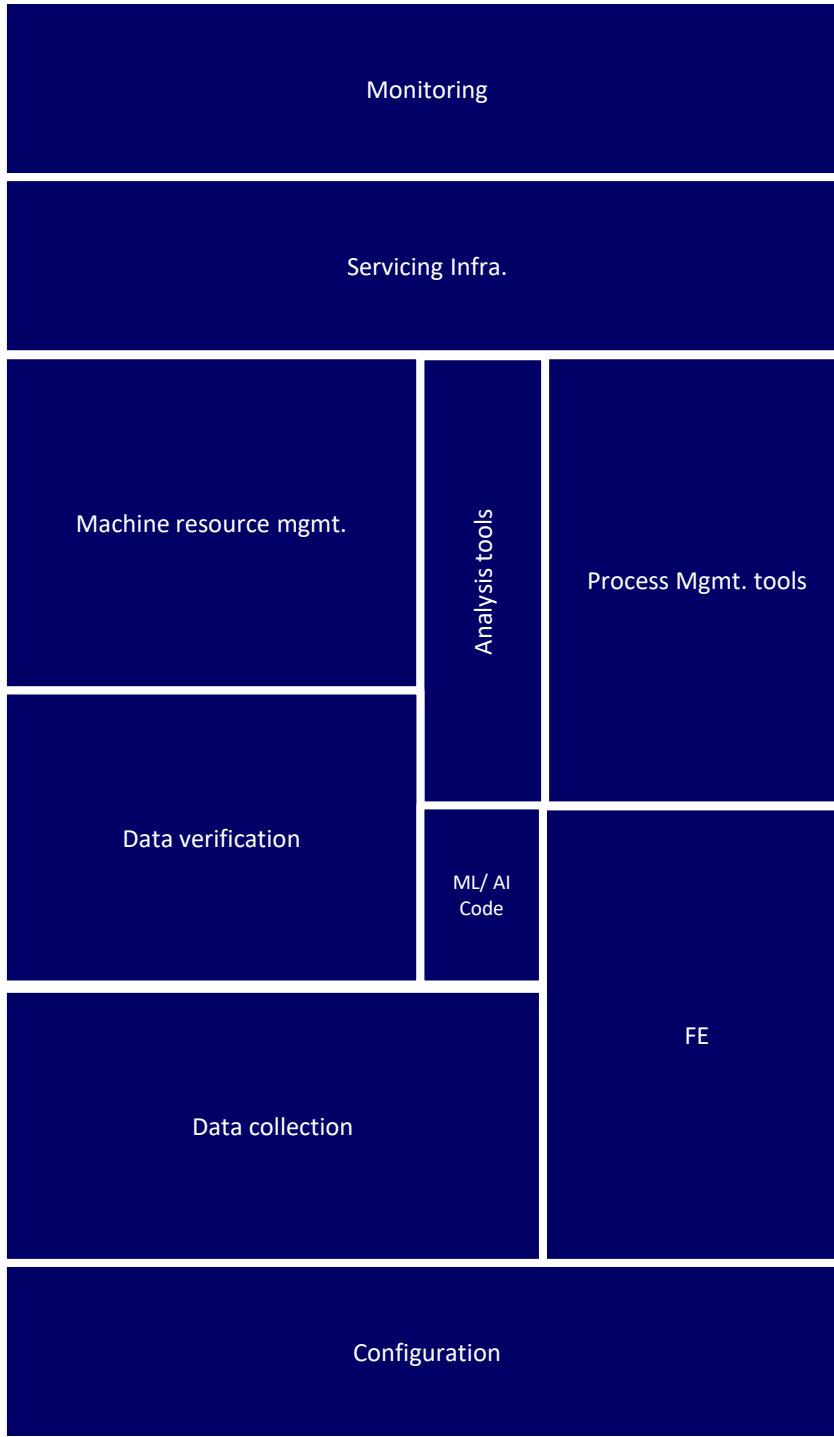
Monitoring

ML/ AI
Models

Analysis Tools

FE

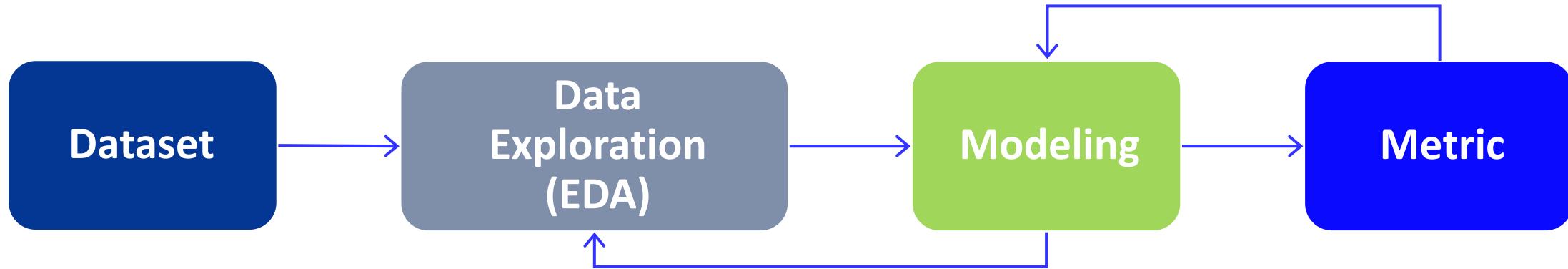
Process Mgmt. Tools



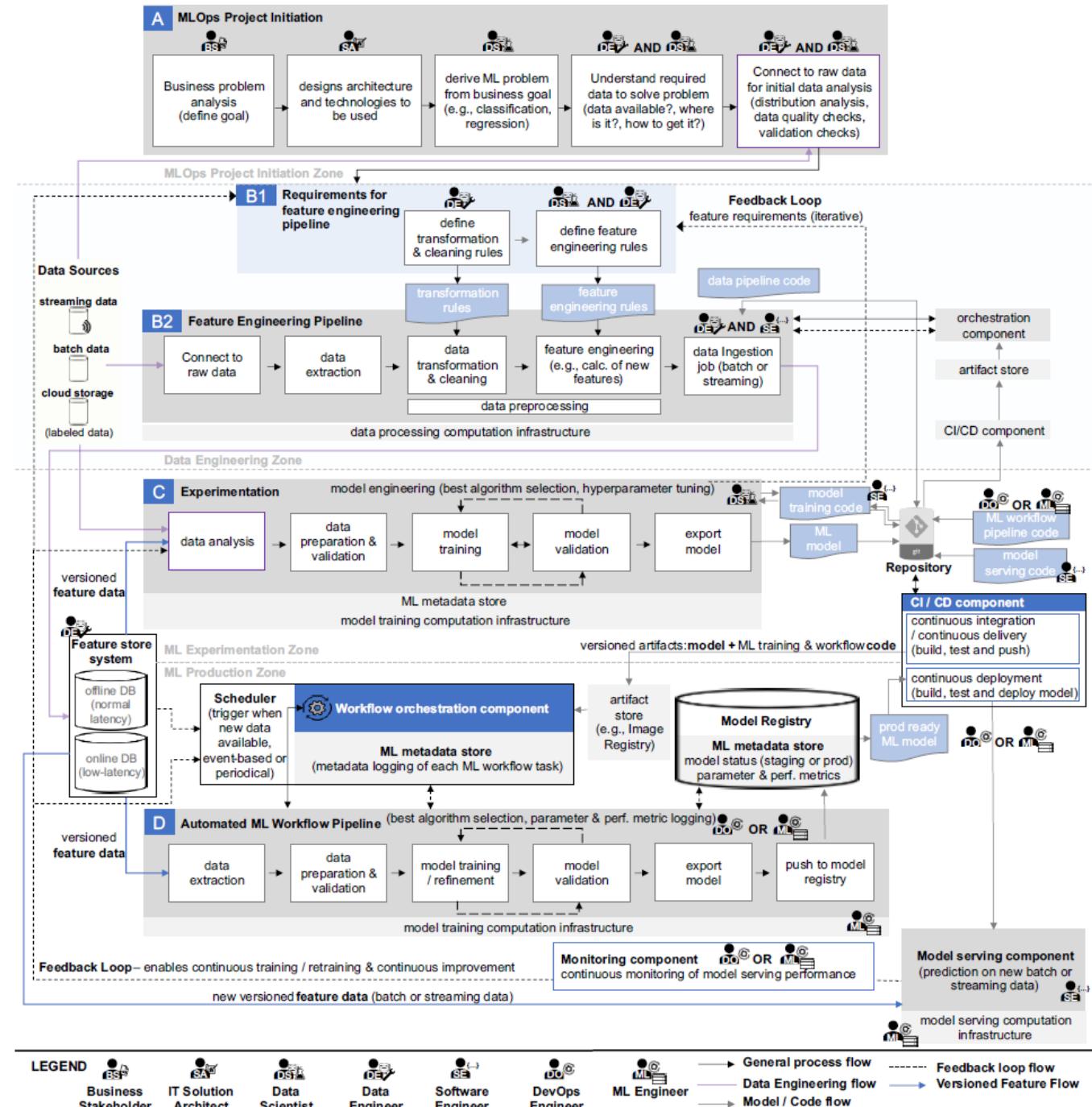
70%

Business & People Transformation

Machine Learning in academia/ Kaggle environments usually focuses on a single objective



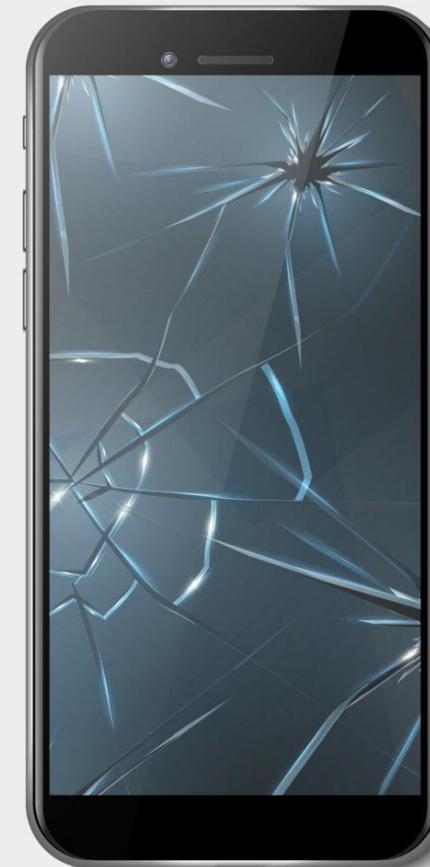
Reality is significantly a more complex affair...



Overcoming the gap between Academia/ Research and Production-Ready ML Solutions

	Academia	Production
Data	Static	Dynamic
Design focus	Highest predictive power	Impact vs. Effort and interpretability
Model training	Best outcome	Continuous pursue of optimal outcome
Responsible AI	Ethically important	Critical/ Liability
Challenge	Model accuracy	Entire system performance & maintenance

Dev vs. Prod





“DevOps is the **union of people, process, and products** to enable **continuous delivery of value** to your end users”

– MS DevOps

“MLOps is a set of **best practices and methods** for an efficient **end-to-end development and operation** of **performant, scalable, reliable, automated and reproducible** ML solutions in a **real production** setting”

- Neptune.ai

“Put simply, **MLOps = ModelOps + DataOps + DevOps**”

- Databricks



DevOps, MLOps, AIOps?

Why not just use DevOps??

Agile principles

Security (Safety)



CI/ CD

Automation of code integration and deployment for faster, reliable releases



IaC

Code-based infrastructure management for **consistent, repeatable** environments



Containerization

Encapsulate applications for easier deployment, scaling, and management



Monitoring

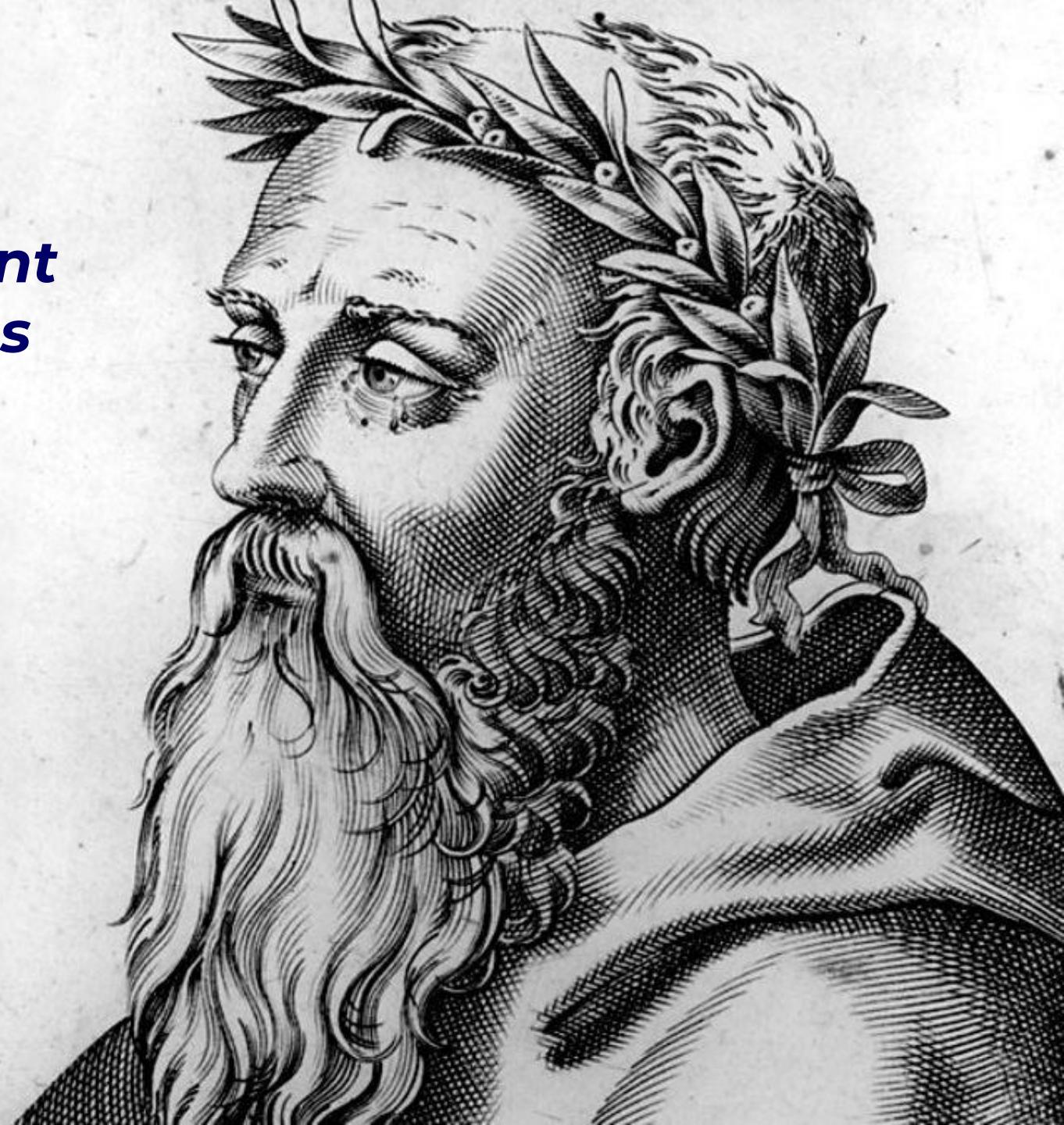
Real-time tracking for system **health** and performance



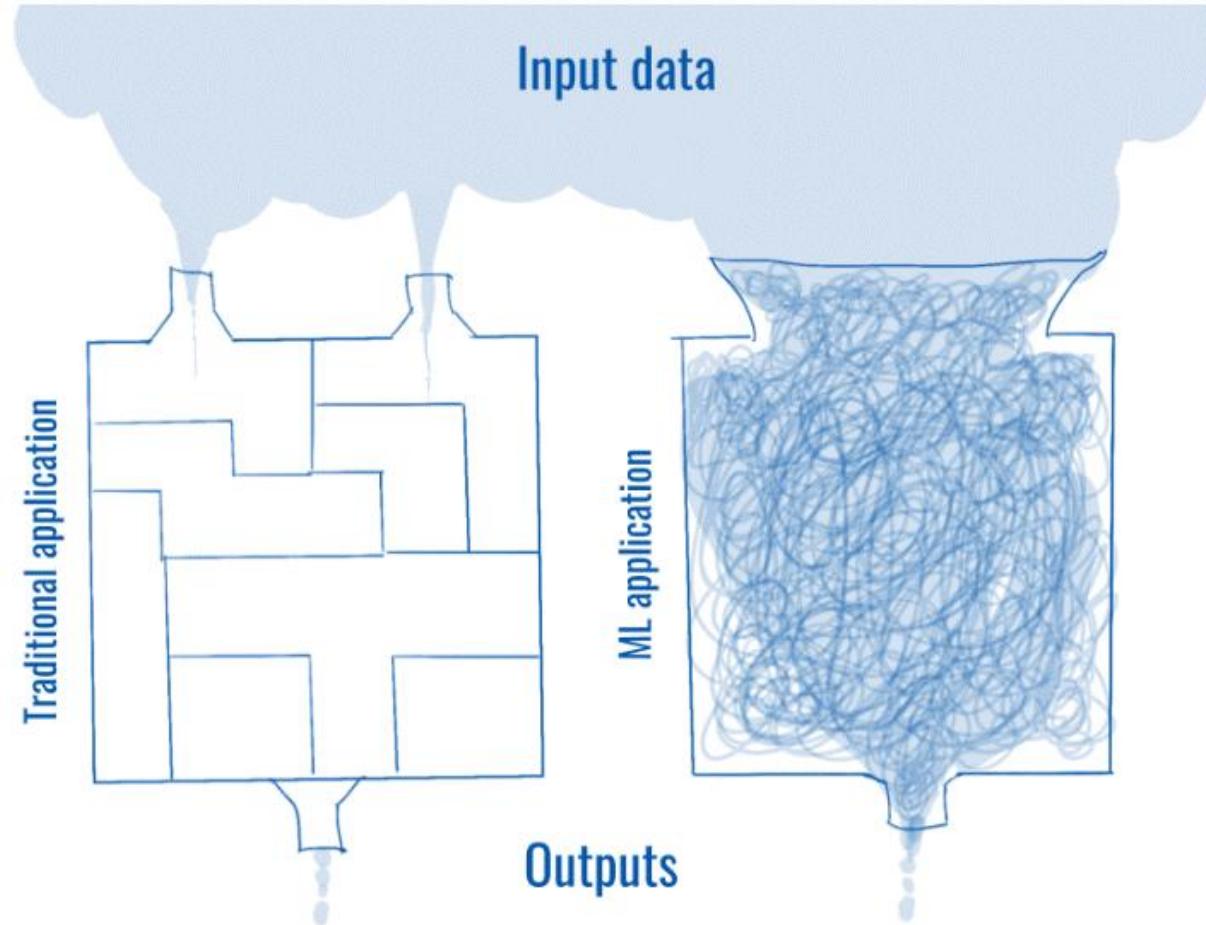
Cloud

Scalable, on-demand resources for **distributed** computing

“There is nothing permanent except change” – Heraclitus



In the world of ML “The only constant, is change...”



- 1 **ML vs Traditional Software:** ML is exposed to the **ever-changing real world** via data, unlike traditional software which operates in a more static environment
- 2 **Development Cycle:** ML apps are built through **trial and error** because they learn from data, not just logical reasoning
- 3 **Skillset Shift:** People building ML apps focus more on data and experimentation, making it more like **empirical science** than typical software engineering

Key differences between DevOps and MLOps

- 1 **Team Skills:** ML teams have AI and ML specialists, **not just software engineers.** They focus on exploring data and building models
- 2 **Development:** ML involves **lots of experimentation** to find the best approach. It's a challenge to **keep track** and reuse code effectively
- 3 **Testing:** Beyond regular tests, ML systems **require checks for data and model quality**
- 4 **Deployment:** ML systems need more complex pipelines to manage **model training and updating**
- 5 **Production:** ML models often **decline in performance over time** due to data changes, needing continuous monitoring (i.e. Data/ Concept drift)

Further more, the CI/ CD framework wasn't designed for the Training (T) and Monitoring (M) of ML models

Continuous Integration (CI)

Not only about **testing and validating code and components**, but also testing and validating **data, schemas, and models**

Continuous Delivery (CD)

Not only about a **single software package** or a service, but a system (an ML **training pipeline**) that should automatically deploy another service (model **prediction service**)

Further more, the CI/ CD framework wasn't designed for the Training (T) and Monitoring (M) of ML models

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Continuous Training (CT)

A new property, **unique to ML systems**, that's concerned with **automatically retraining candidate models for testing and serving**

Continuous Monitoring (CM)

Not only about **catching errors** in production systems, but also about monitoring production **inference data and model performance metrics** tied to business outcomes

But is not one or the other, but the best of both worlds what ensures successful ML models delivery

