MLOps: get your ML apps ready for production

Francesco Tamborra

NMLM, 12/12/2022 – Nantes

Outline

- ✦ Intro: What & why

`requirements.txt`
✦ ML development VS standard development ✦ ML lifecycle

- ✦ MLOps maturity levels
- ✦ Tools overview
- ✦ `@app.get("/predictions")`

What is MLOps ?

"The ability to apply DevOps principles to Machine Learning applications"

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MLOps is an ML engineering **culture and practice** that aims at unifying ML system development (Dev) and ML system operations (Ops).

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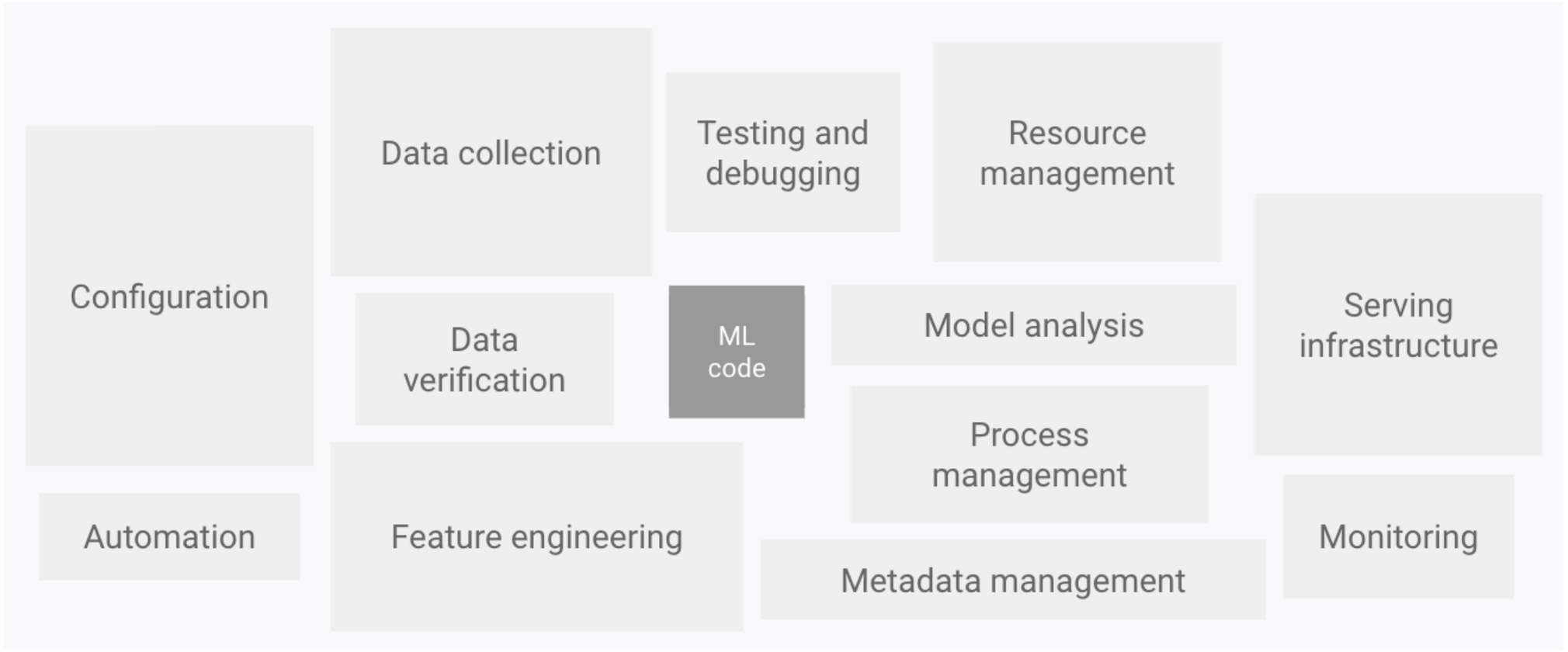

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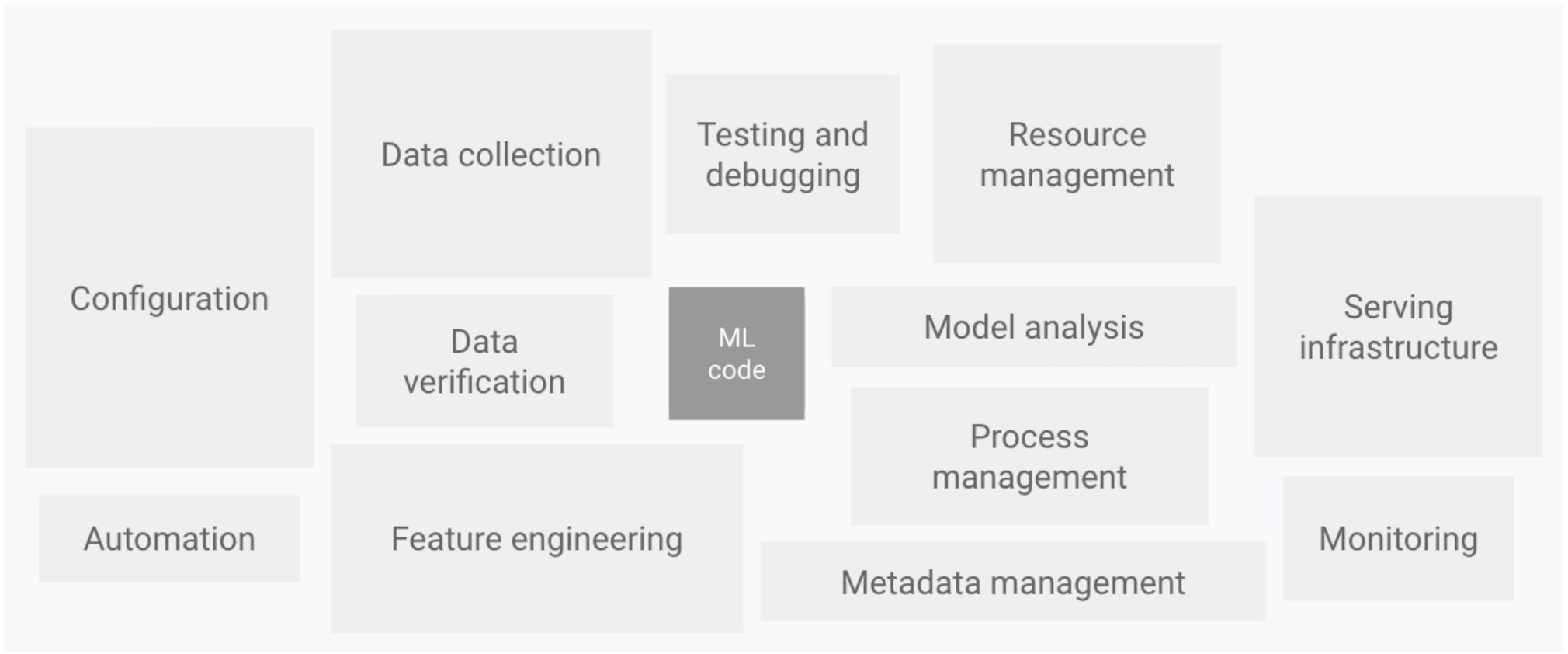

Global MLOps Market Size estimated at 612 USD million in 2021 and projected to reach 6.1 USD billion by 2028

Why MLOps ?

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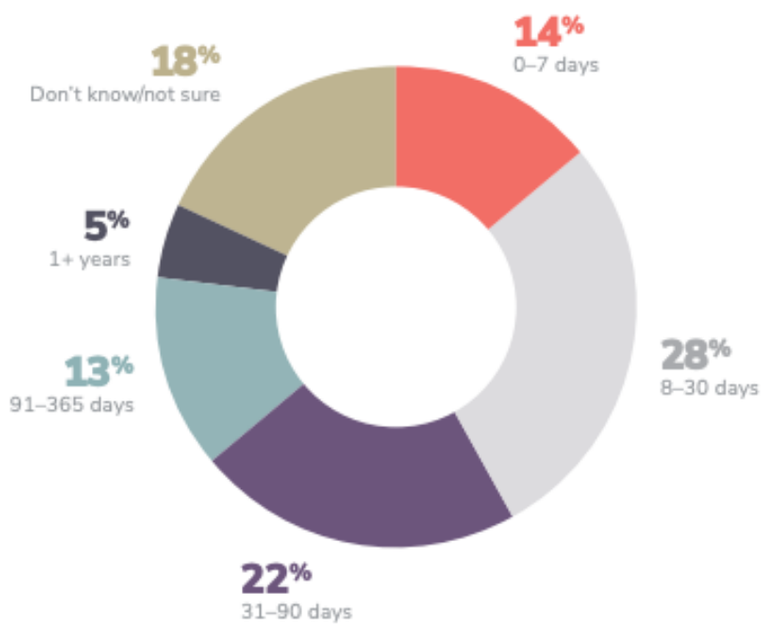

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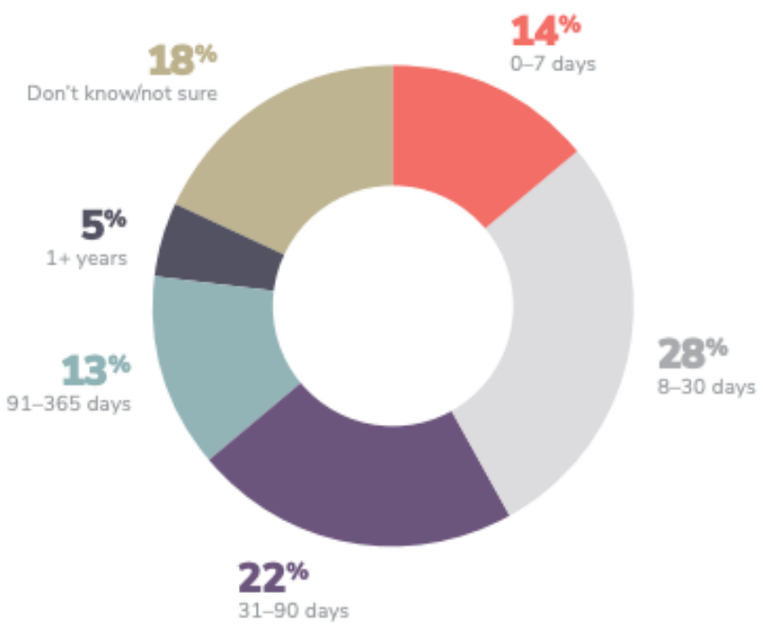
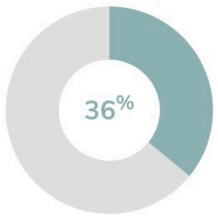


What percentage of your data scientists' time is spent deploying ML models?



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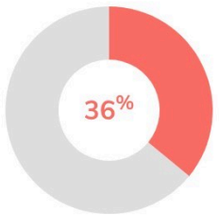
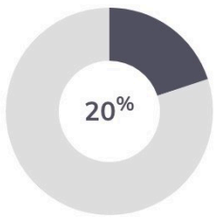
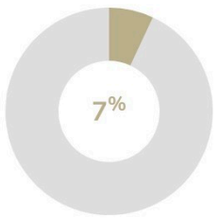


36% of survey participants said their data scientists spend **a quarter to half** of their time deploying ML models



20% of survey participants said their data scientists spend **half to three-quarters** of their time deploying ML models



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1% of respondents said they were unsure.

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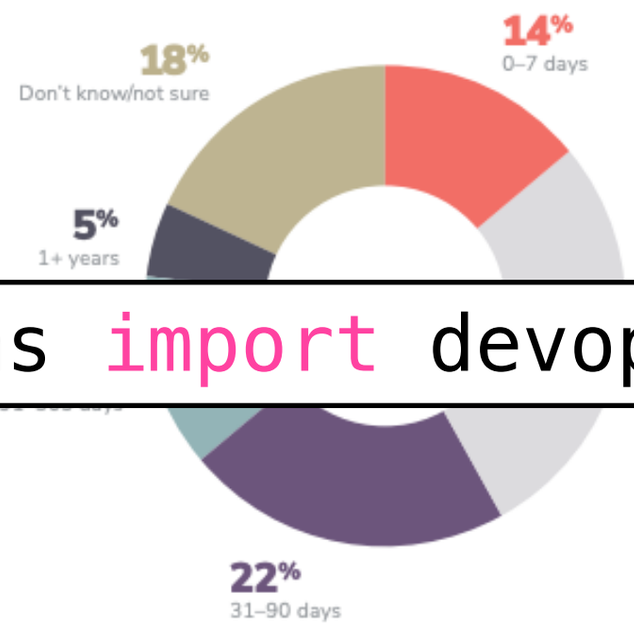


```
from DevelopmentOperations import devops
```

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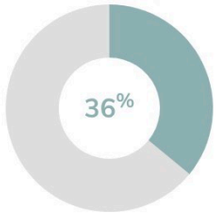

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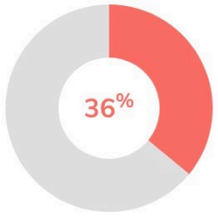

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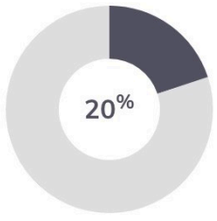

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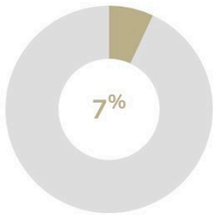

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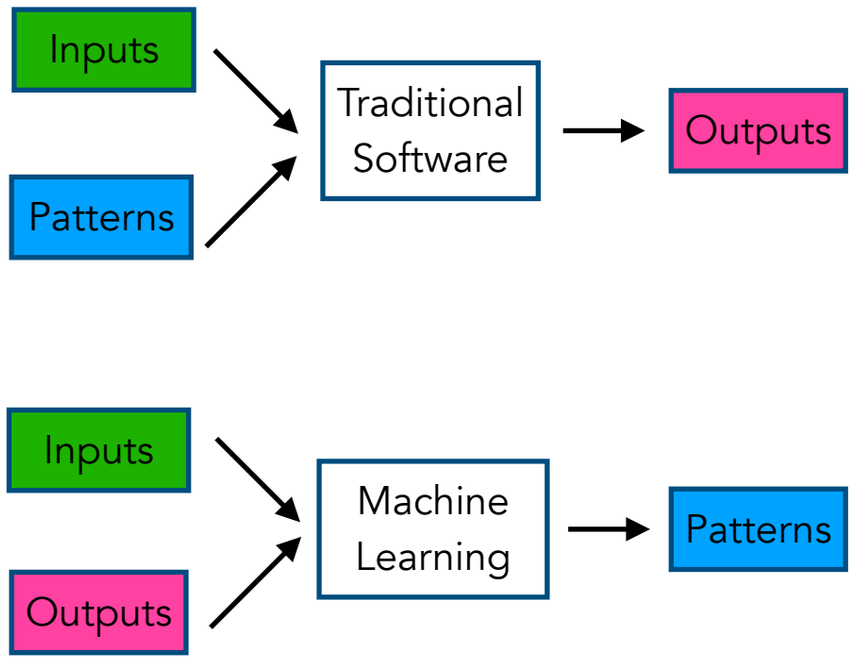

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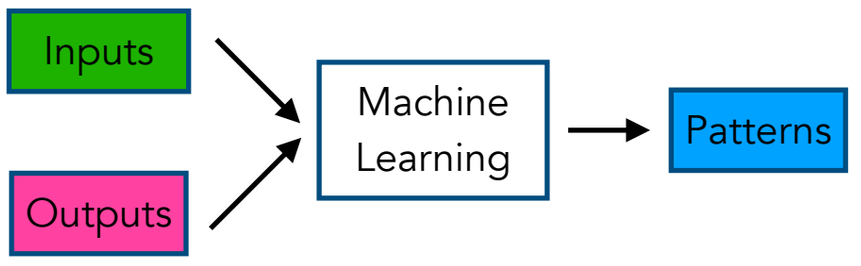

Andrej Karpathy

Nov 11, 2017 · 9 min read · Listen

Software 2.0

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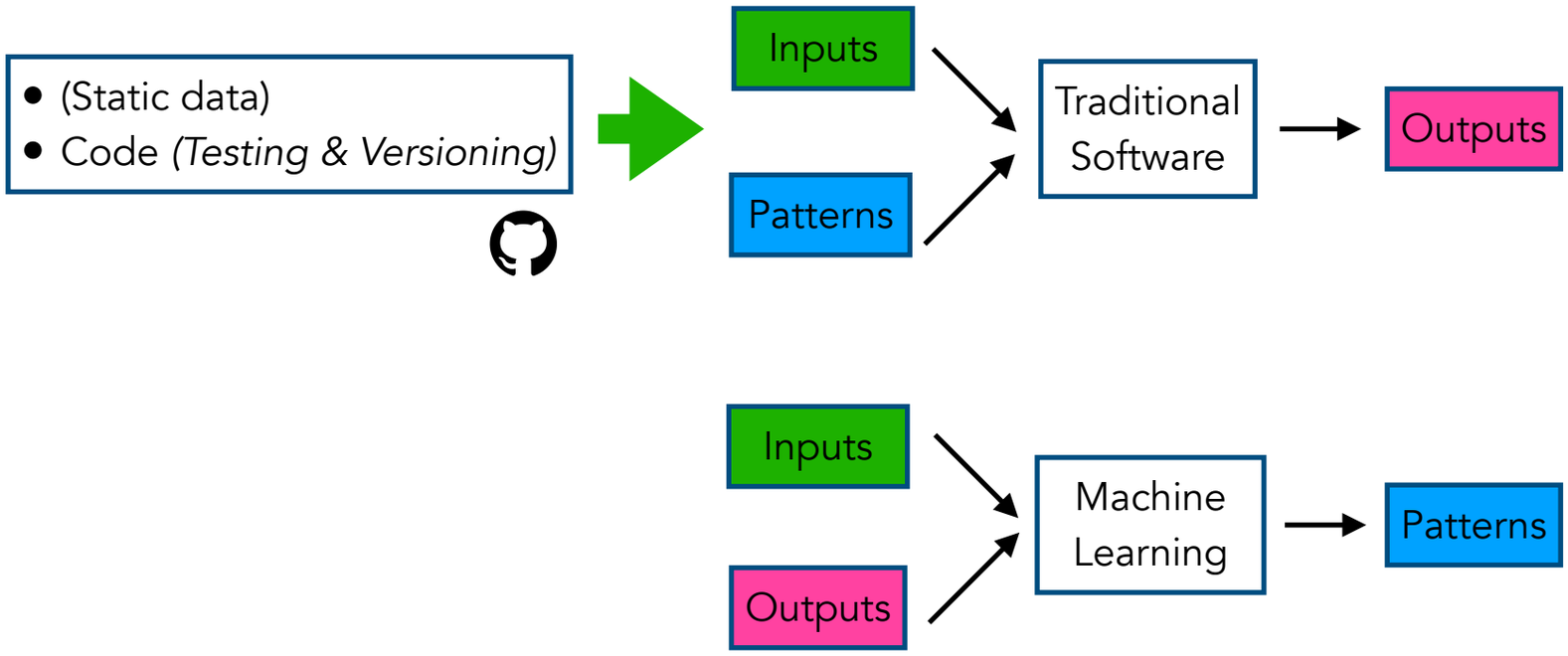

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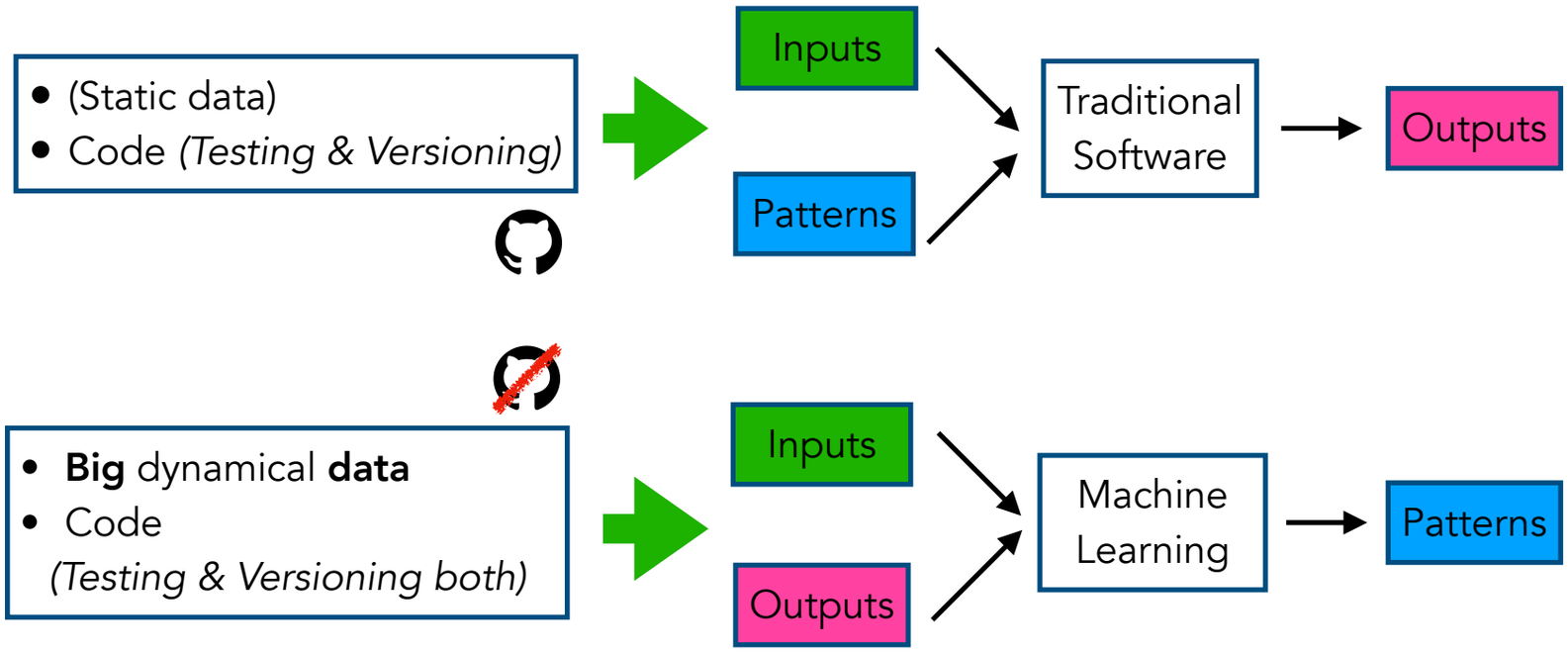

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Software 2.0

ML Dev VS standard SW Dev

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- Code *(Testing & Versioning)*

Inputs + Patterns → Traditional Software → Outputs

- **Big** dynamical **data**
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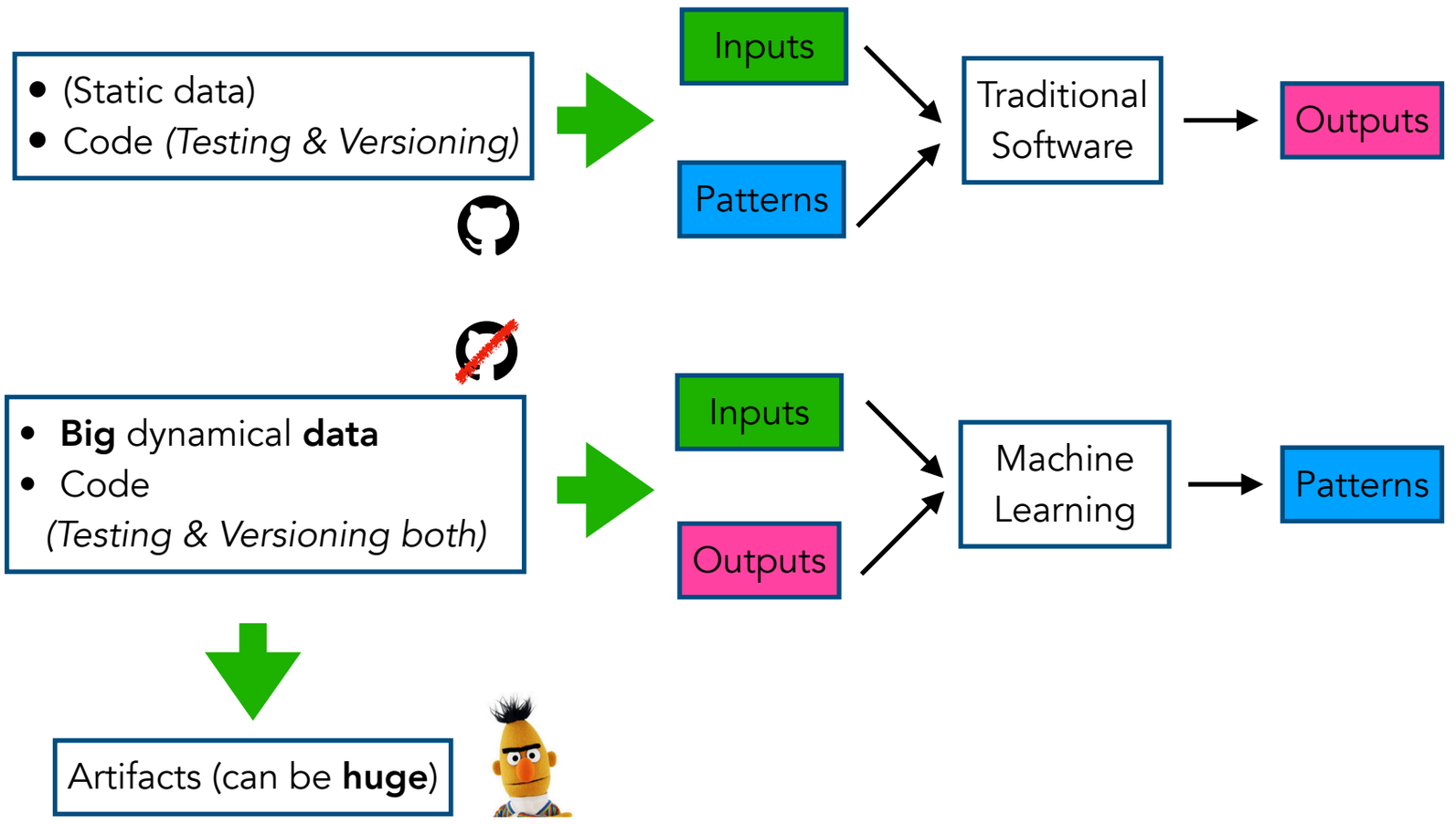

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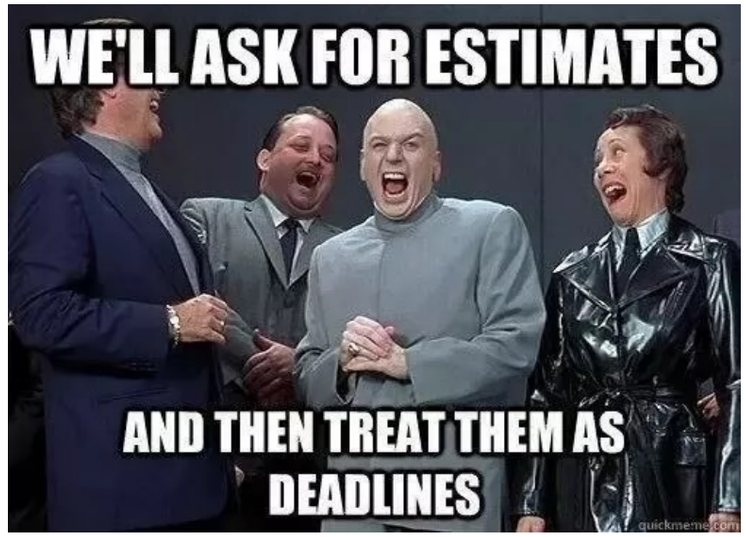

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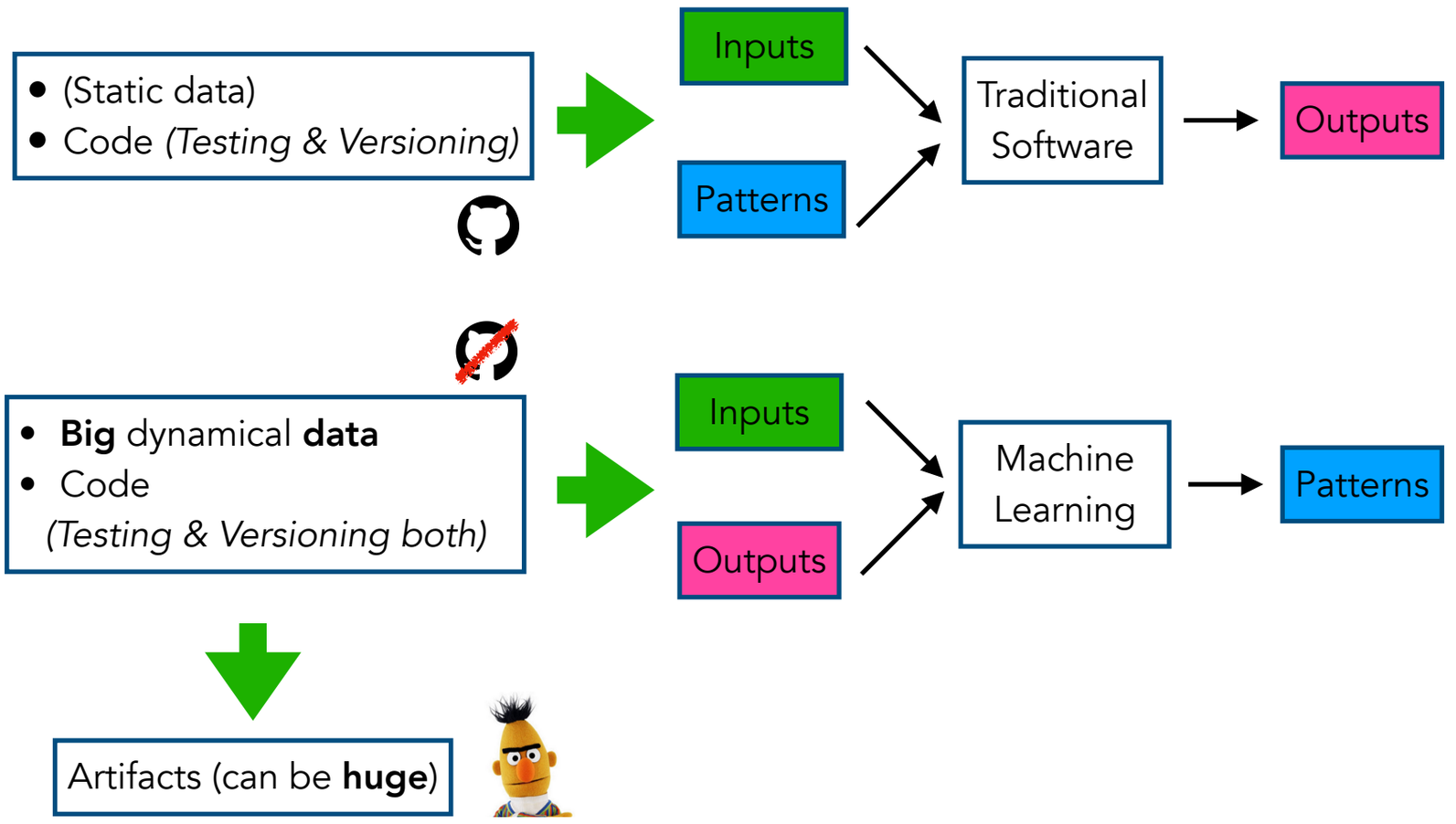

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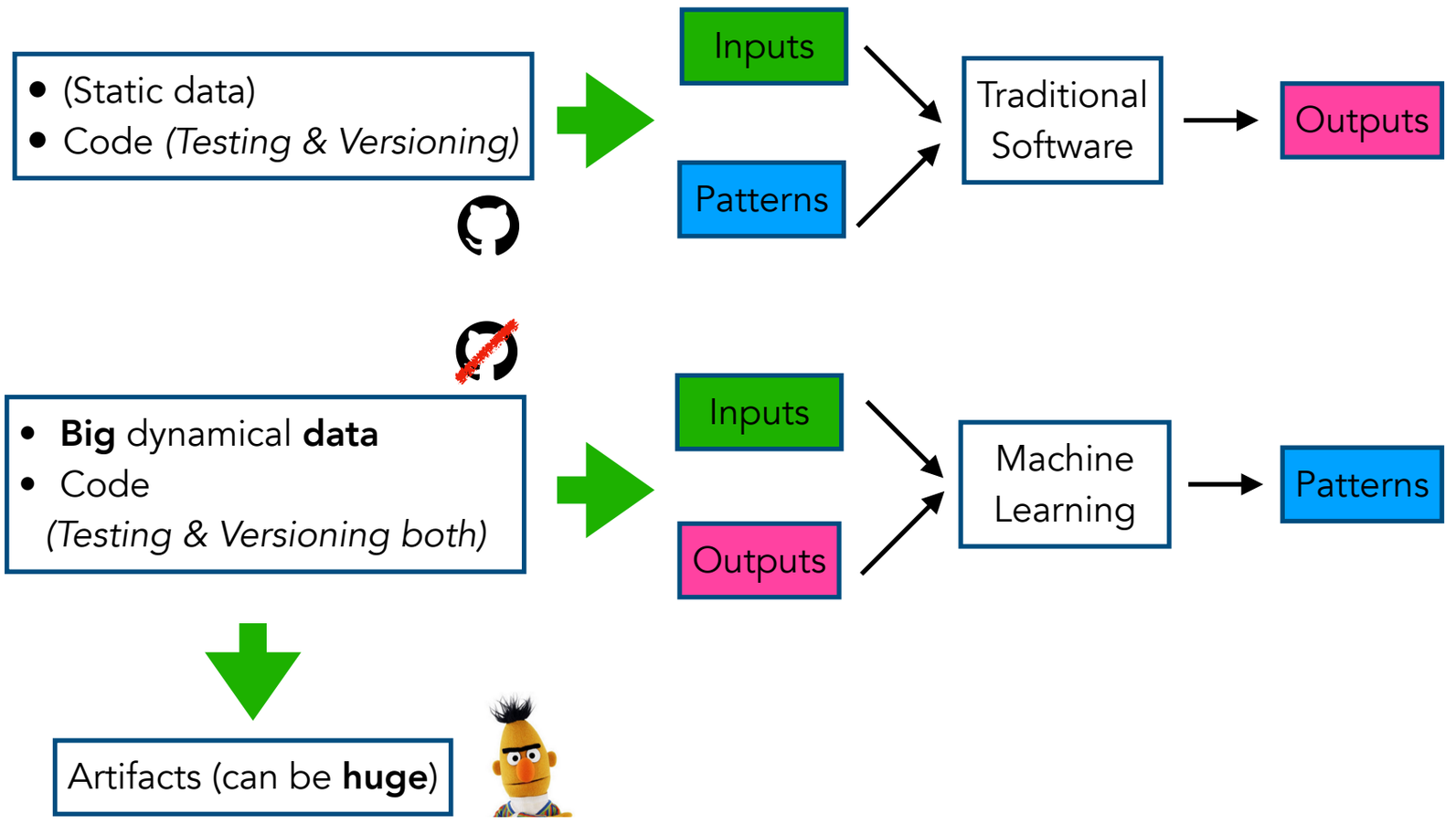

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Production	**Models can decay** in more ways than conventional software systems, and you need to consider this degradation by **tracking summary statistics** of your data and **monitor the online performance**

DevOps VS MLOps in a nutshell

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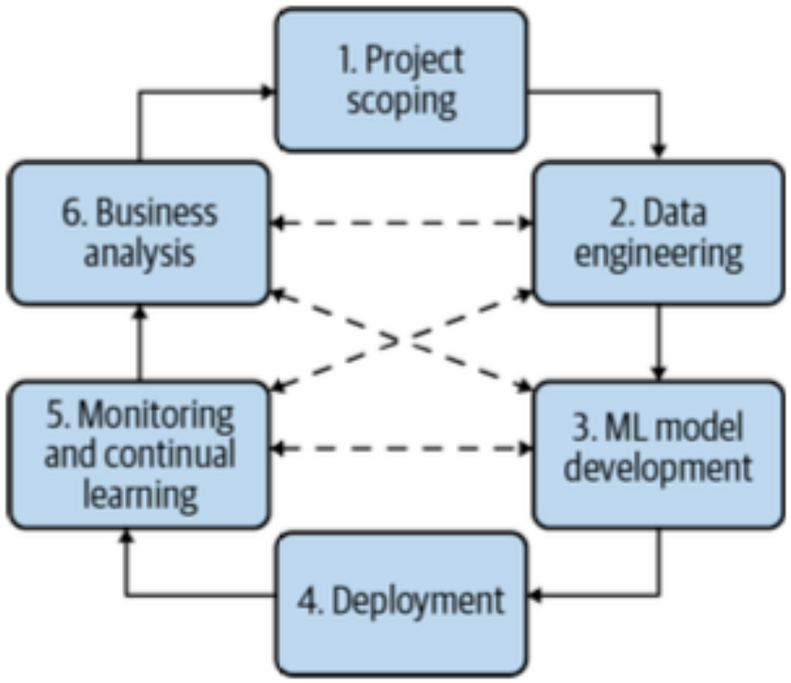
CI is no longer only about testing and validating code and components, but also testing and validating data, data schemas, and models.

CD is no longer about a single software package or a service, but a system (an ML training pipeline) that should automatically deploy another service (model prediction service).

CT is a new property, unique to ML systems, that's concerned with automatically retraining and serving the models.

ML Lifecycle



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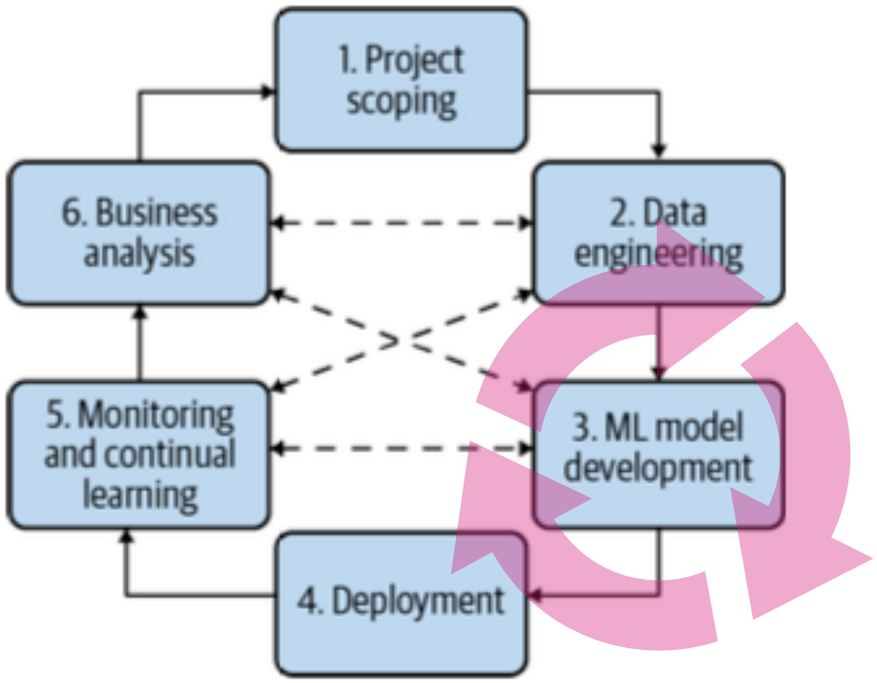

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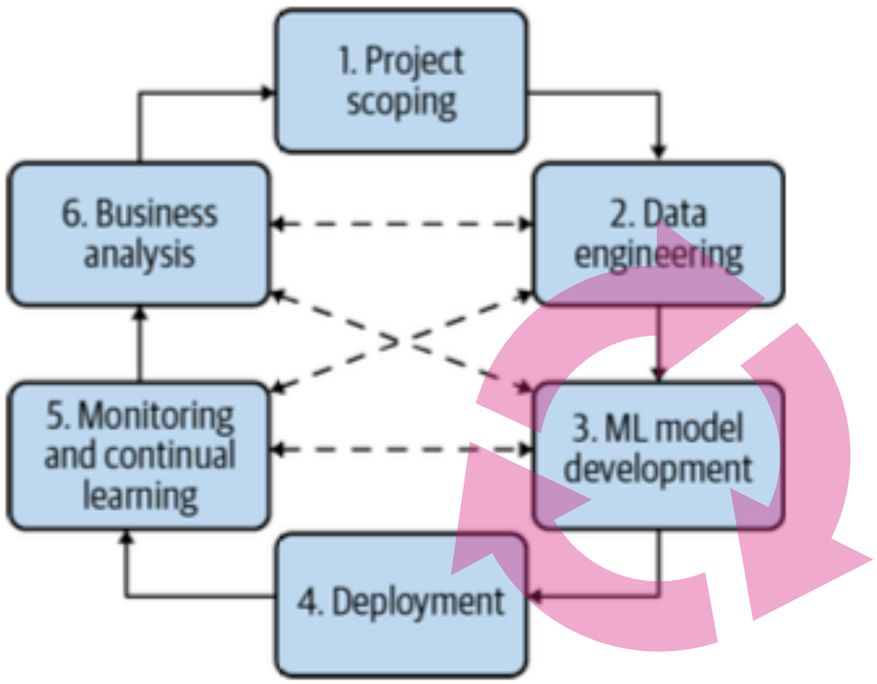

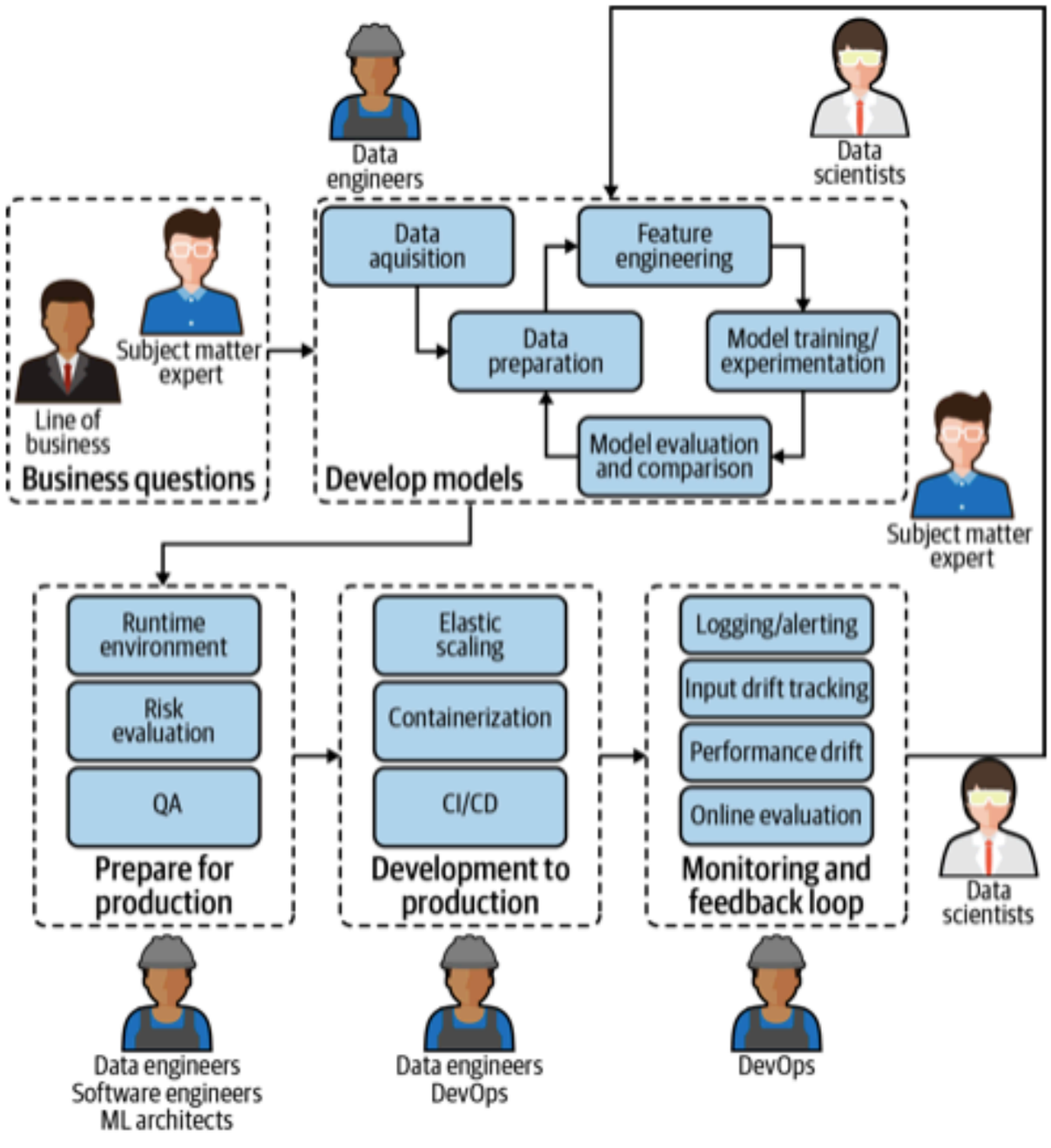

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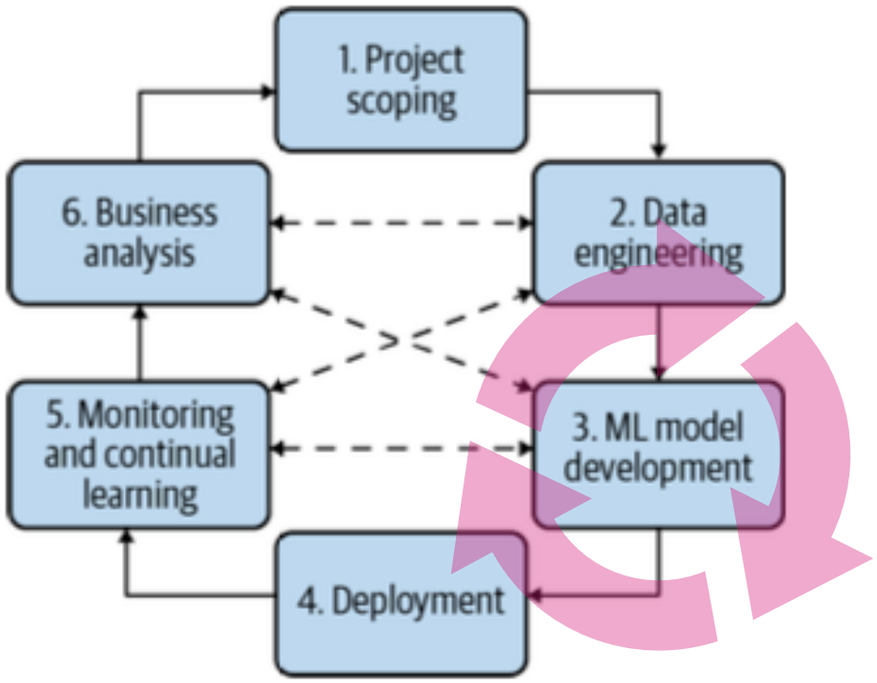
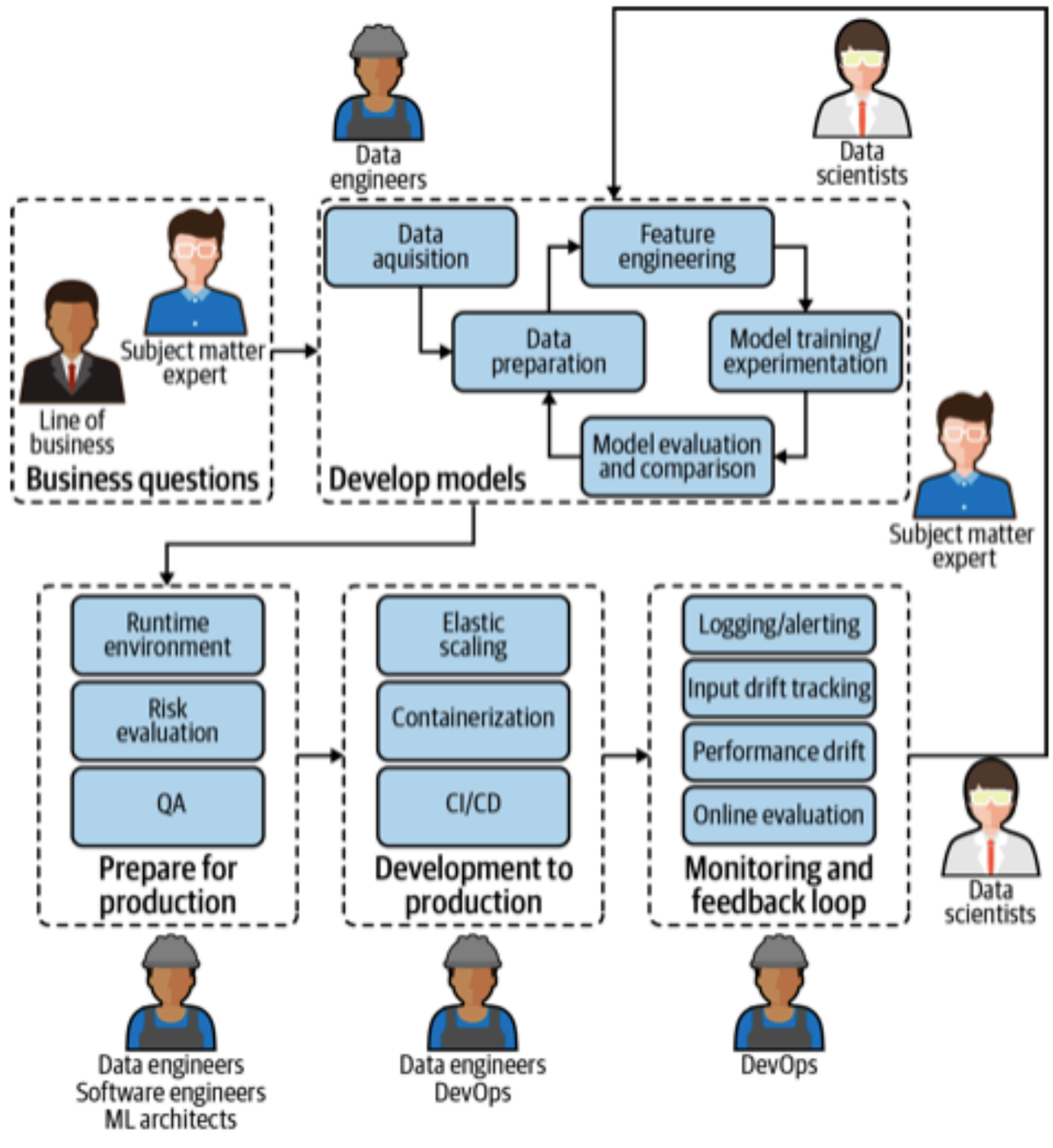


The **level of automation** of these steps defines the **maturity** of the ML process, which reflects the **velocity** of training new models given new data or new implementations



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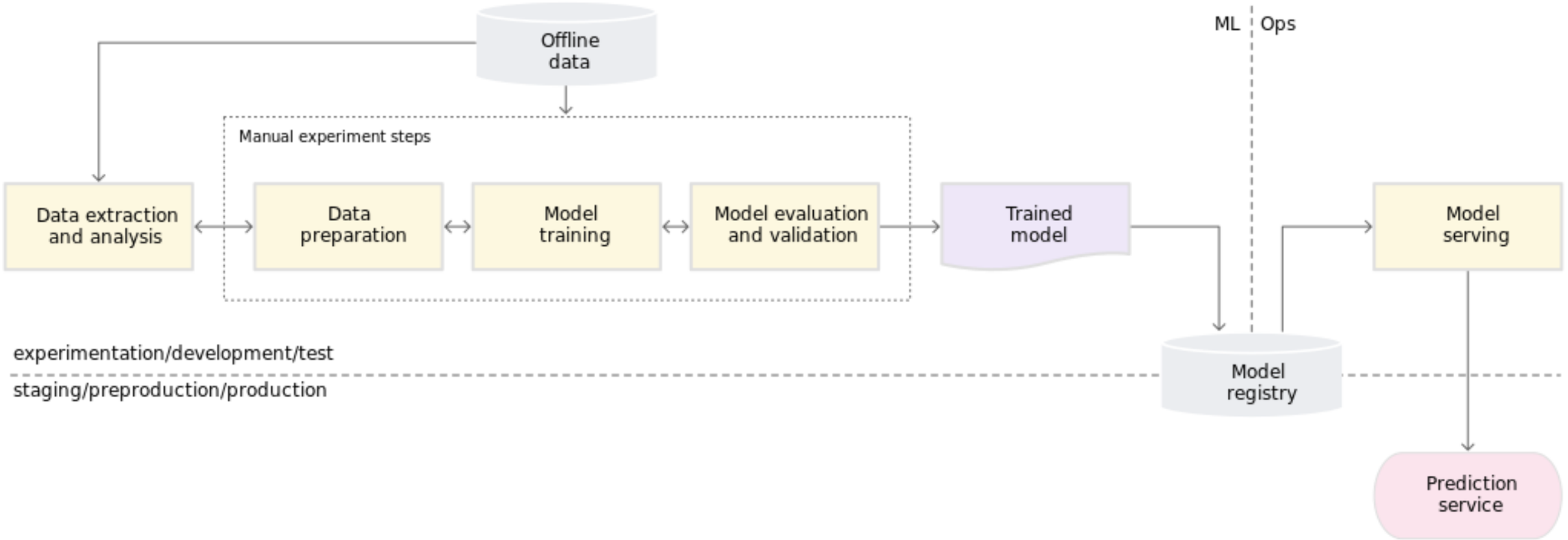

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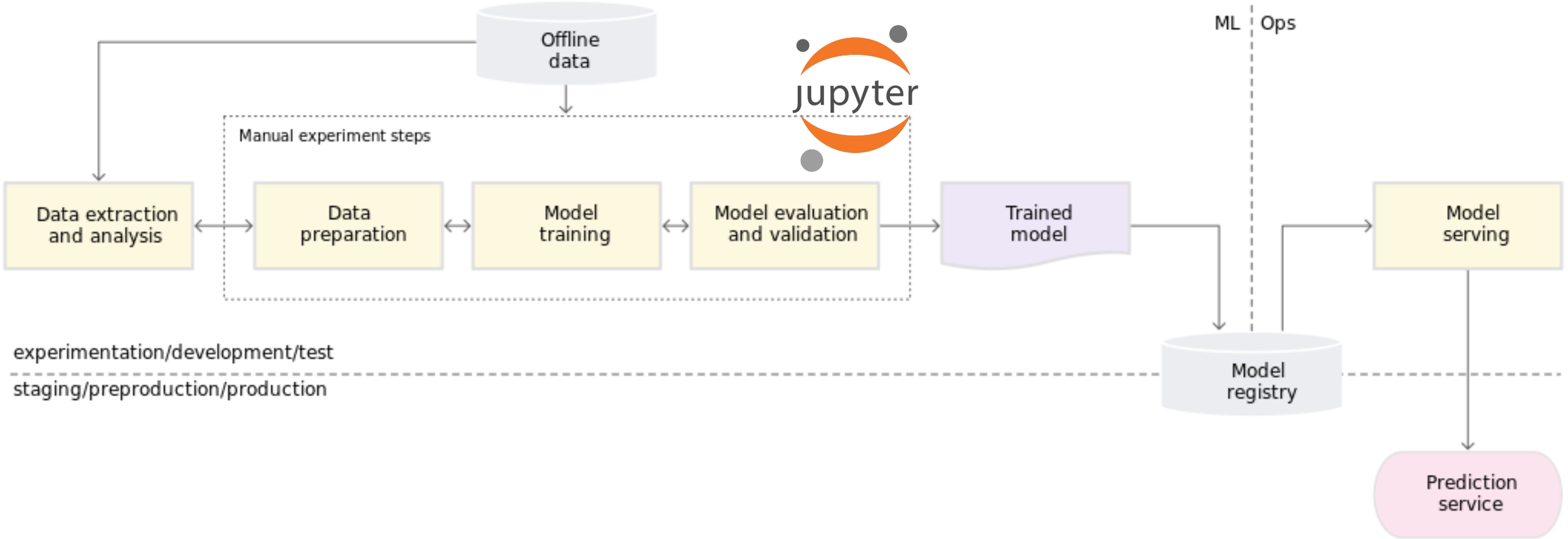

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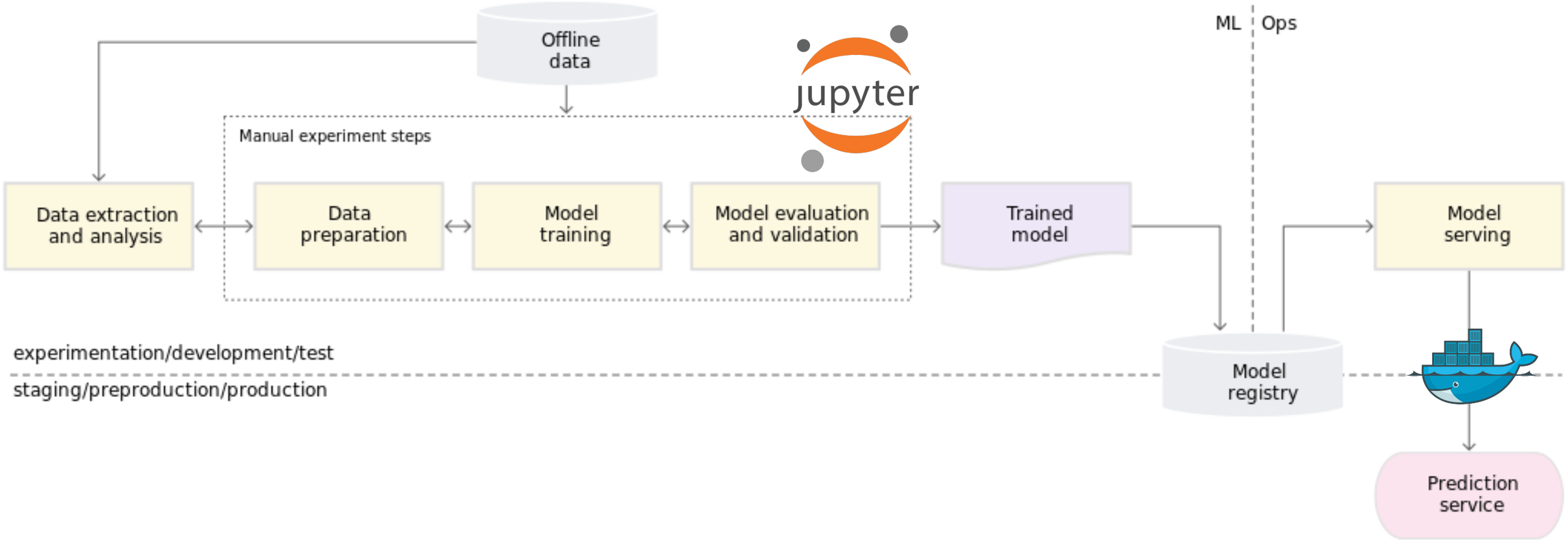

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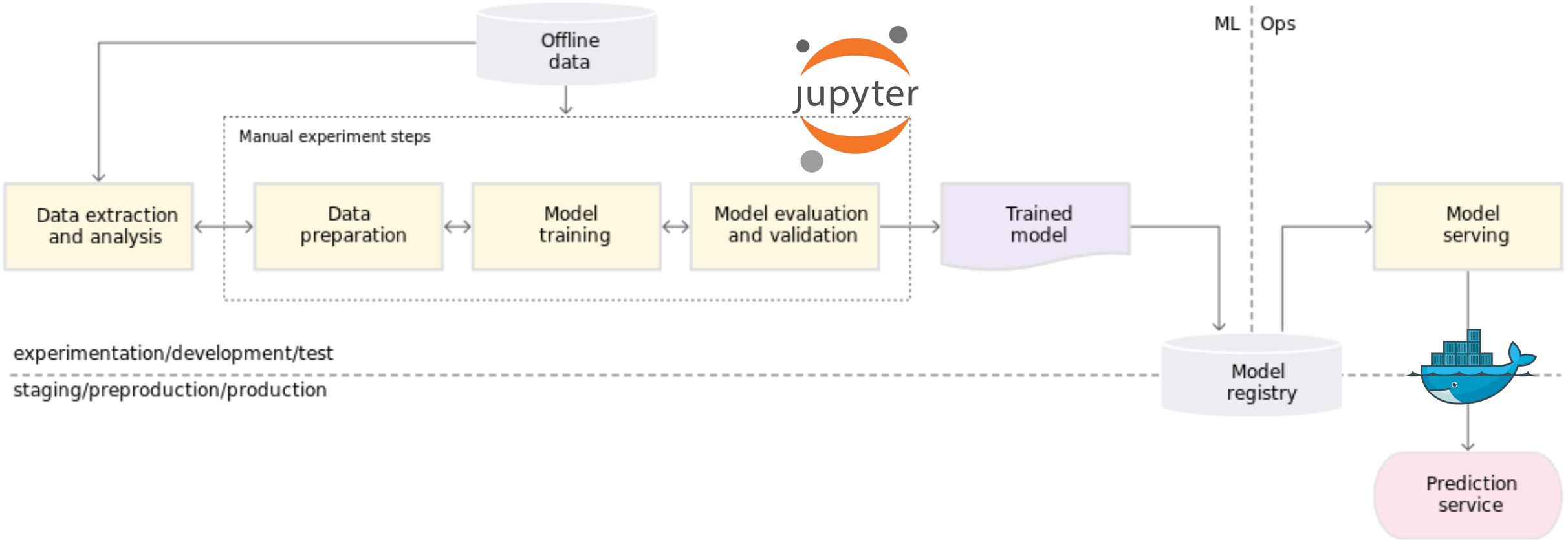

	Dev	Prod
Scale	• usually one instance • no need to worry about autoscaling	• multiple istances/nodes • you most certainly want autoscaling
State	stateful: reproducible but inflexible • install dependencies once and forget • can persist data in dedicated storage	inherently stateless: flexible but hard to reproduce • need to install dependencies on any new instance • need to figure out how to persist data/state across instances

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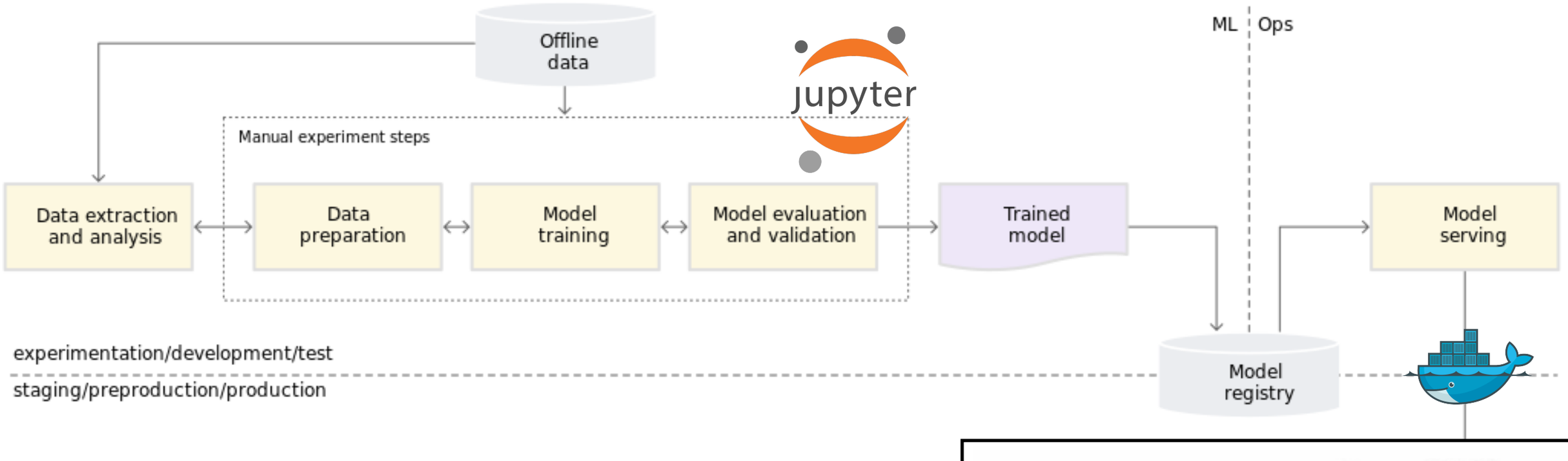

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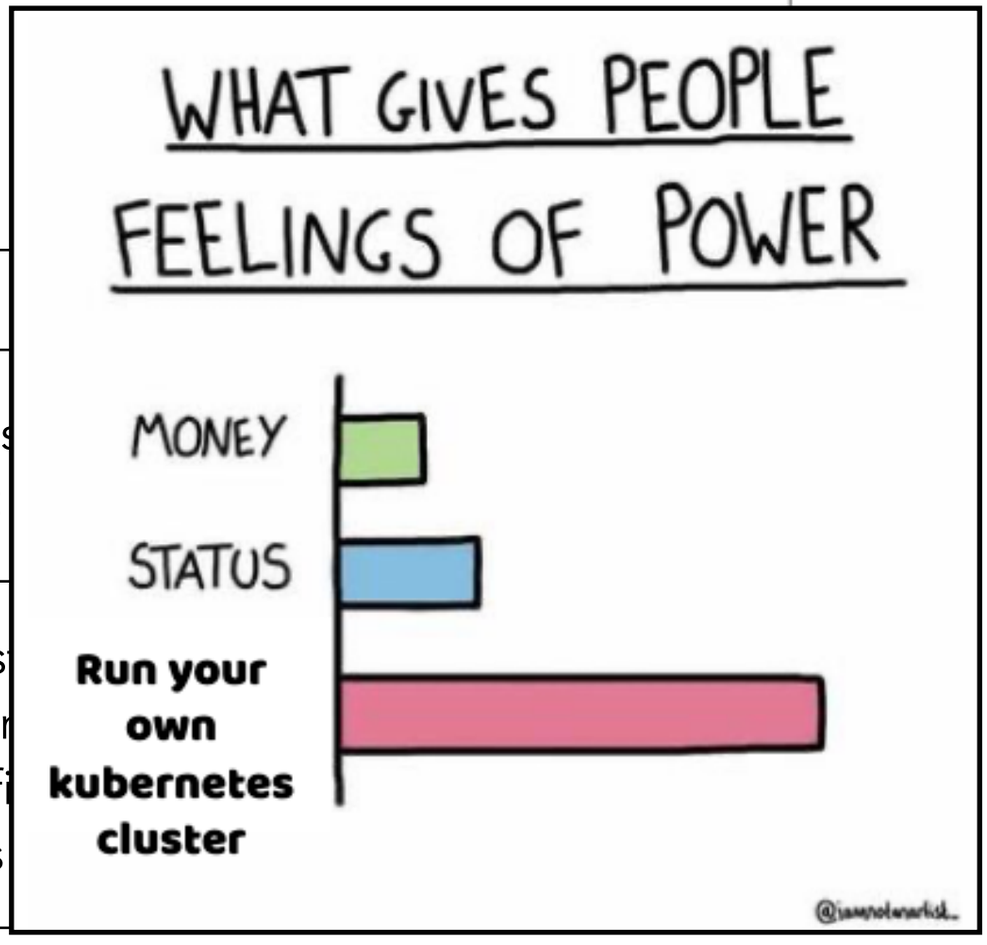

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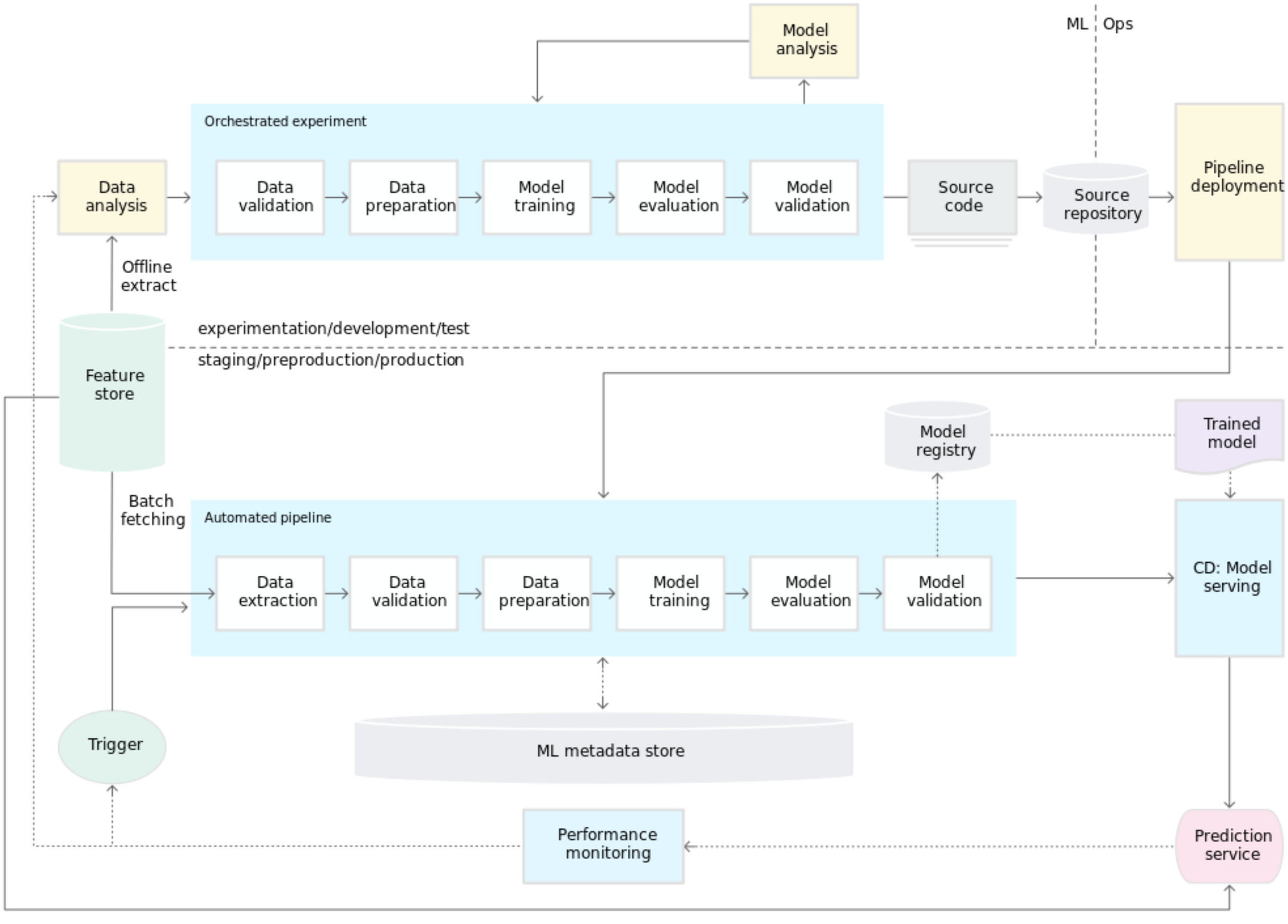

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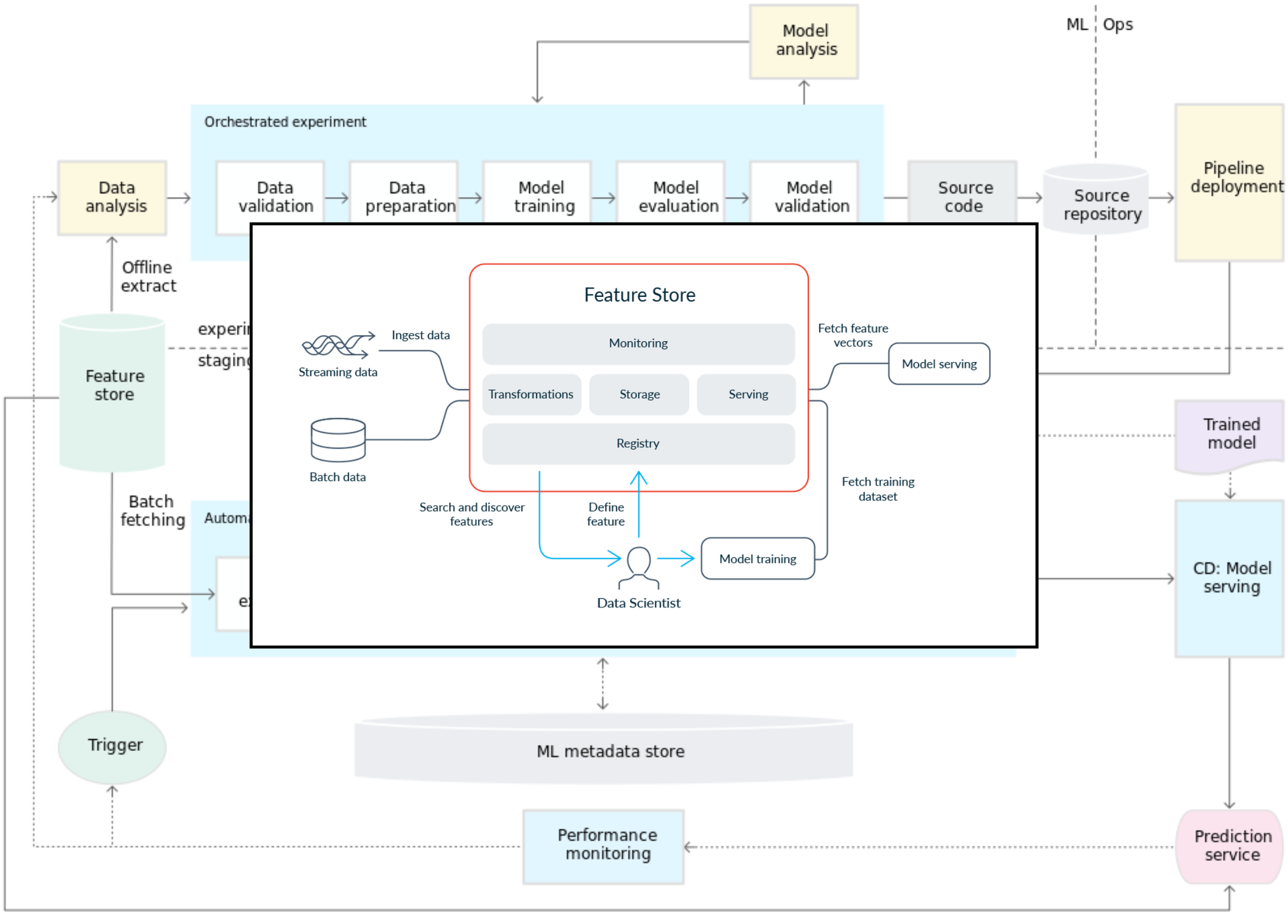

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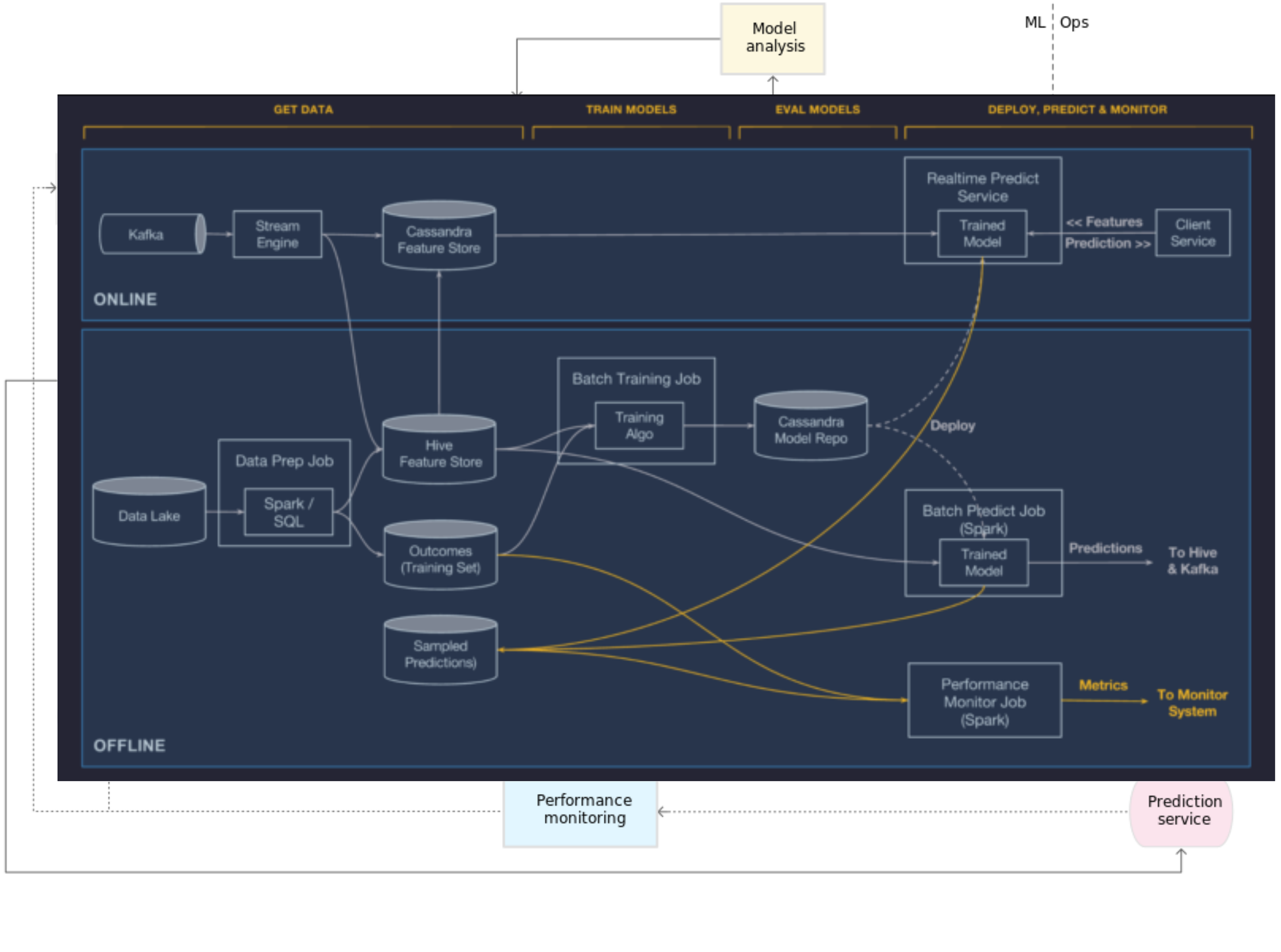

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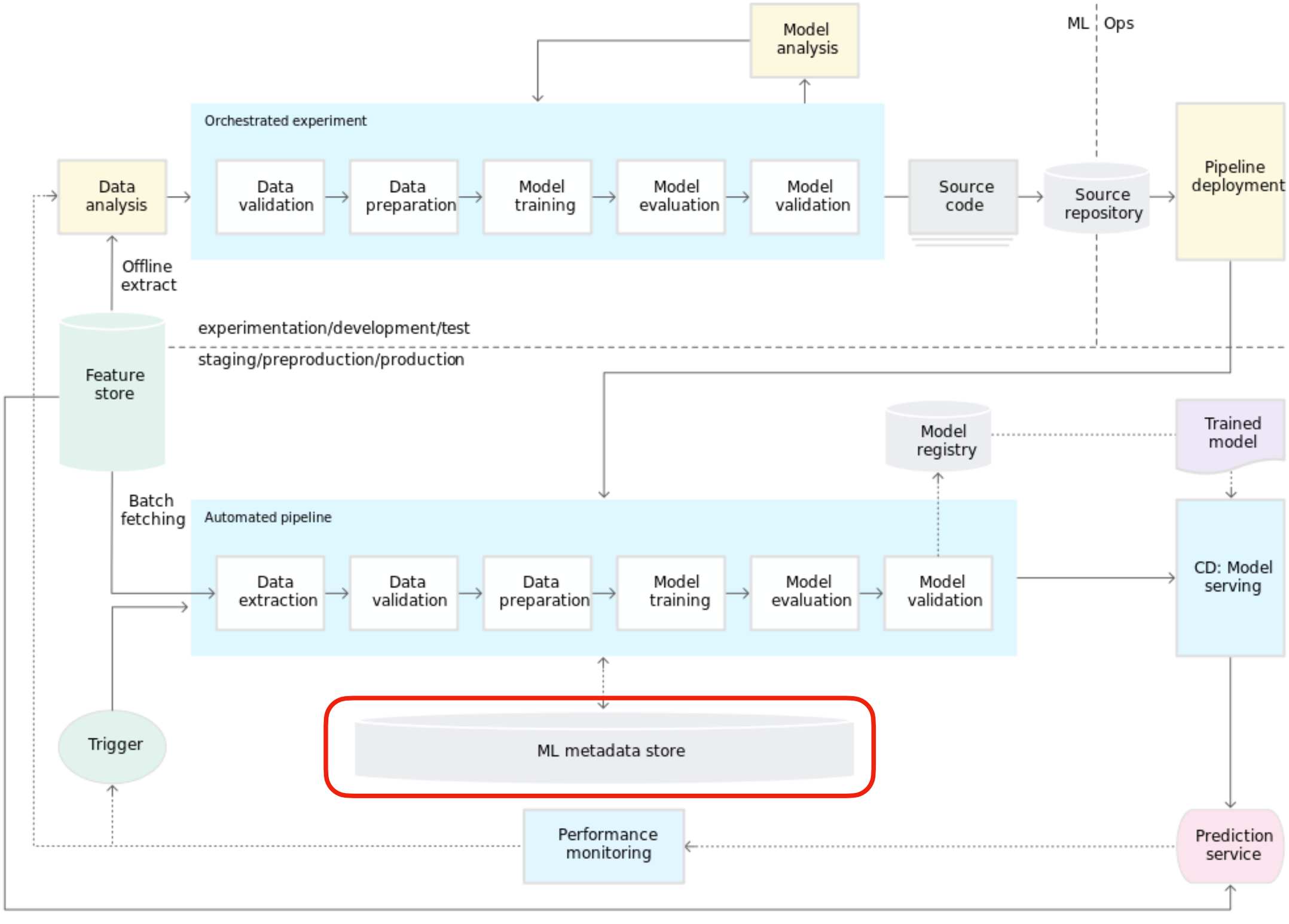

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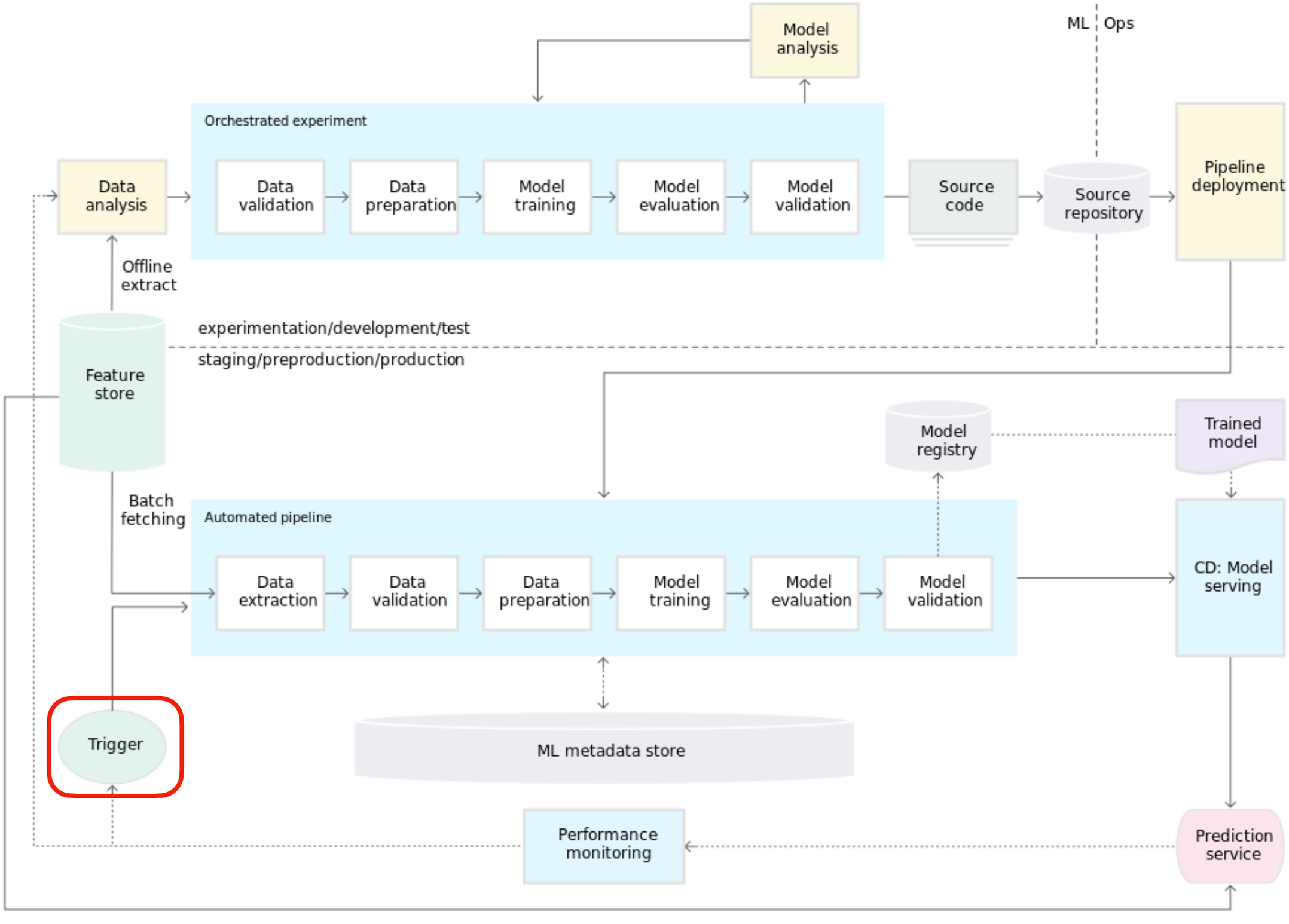
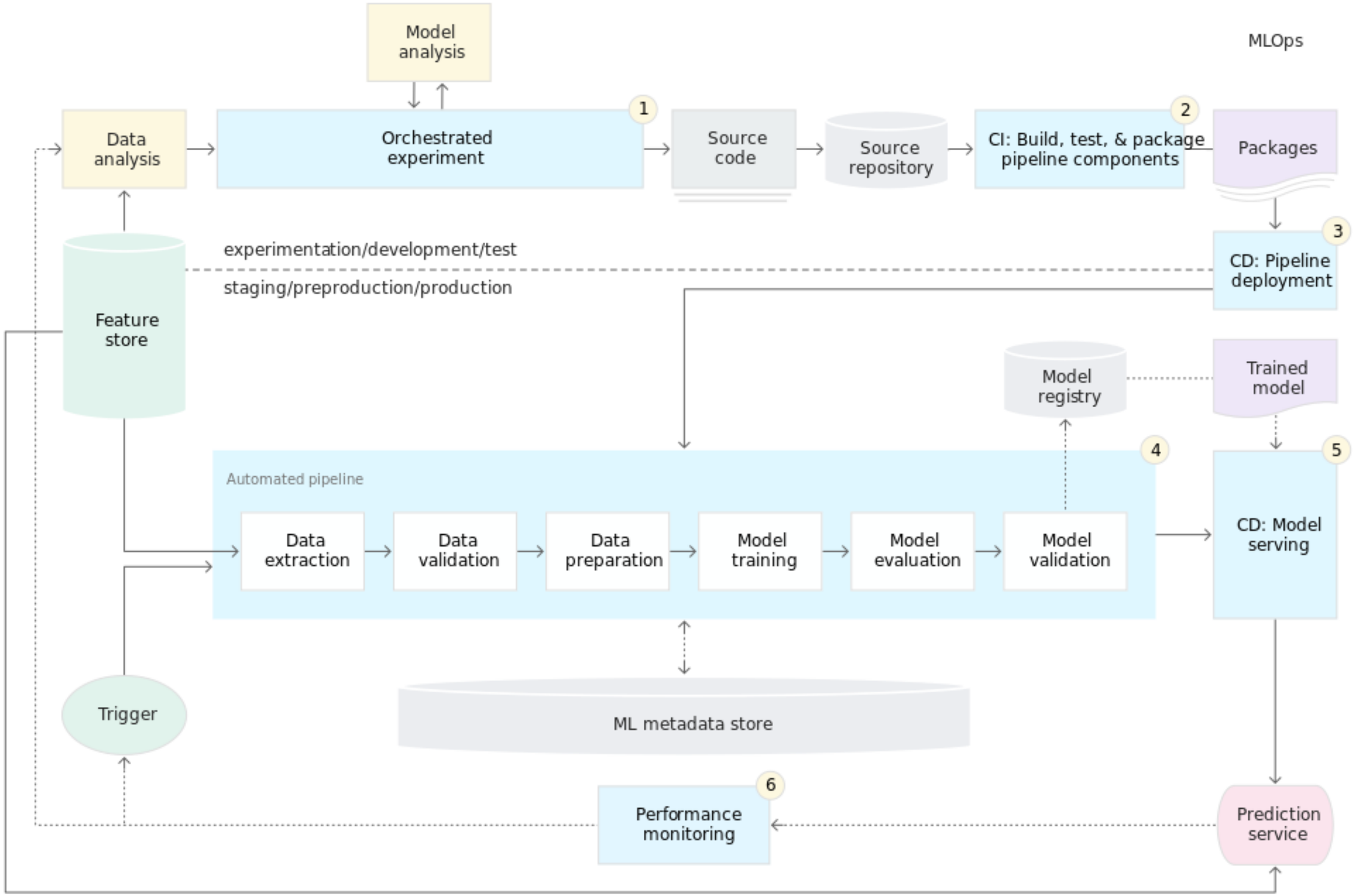


MLOps level 2



Summary

Summary

Implementing ML in a production environment doesn't **only** mean deploying your model as an API **for prediction** but rather deploying an ML pipeline that can **automate the retraining and deployment** of new models.

Setting up a **CI/CD** system enables you to **automatically test and deploy** new pipeline implementations.

This system lets you **cope with rapid changes** in your data and business environment.

You don't have to immediately move all of your processes from **one level to another**.

MLOps tools

MLOps tools

BIG DATA & AI LANDSCAPE 2018

INFRASTRUCTURE

HADOOP ON-PREMISE
cloudera · Hortonworks · MAPR · Pivotal · IBM InfoSphere · bluedata · jethro

HADOOP IN THE CLOUD
aws · Microsoft Azure · Google Cloud · IBM InfoSphere BigInsights · TREASURE DATA · Qubole · altiscale · CAZENA · CenturyLink

STREAMING / IN-MEMORY
aws · databricks · striim · confluent · GridGain · ORACLE Coherence · dataArtisans · hazelcast · TERRACOTTA · kx · FASTDATA · Wallaroo LABS

NoSQL DATABASES
Google Cloud · aws · ORACLE · Microsoft Azure · mongoDB · MarkLogic · AEROSPIKE · DATASTAX · ArangoDB · Couchbase · redislabs · SCYLLA

NewSQL DATABASES
SAP HANA · Clustrix · nuoDB · Pivotal · Cloud Spanner · Cockroach LABS · MEMSQL · influxdata · MariaDB · TIMESCALE · VOLTDB · citusdata · splice MACHINE · paradigm4 · Trafodion · TiDB

GRAPH DBs
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Final 2018 version, updated 07/15/2018

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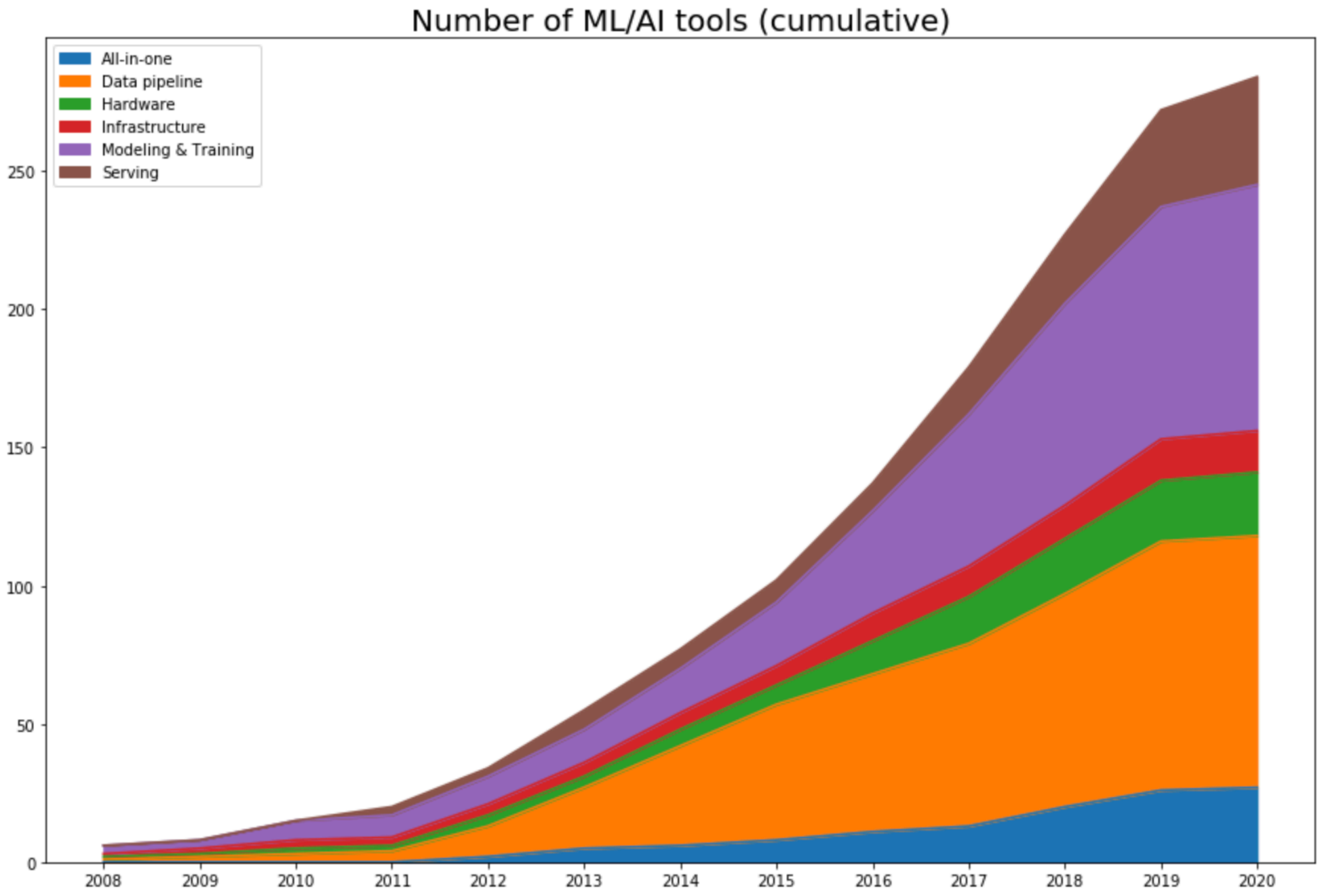
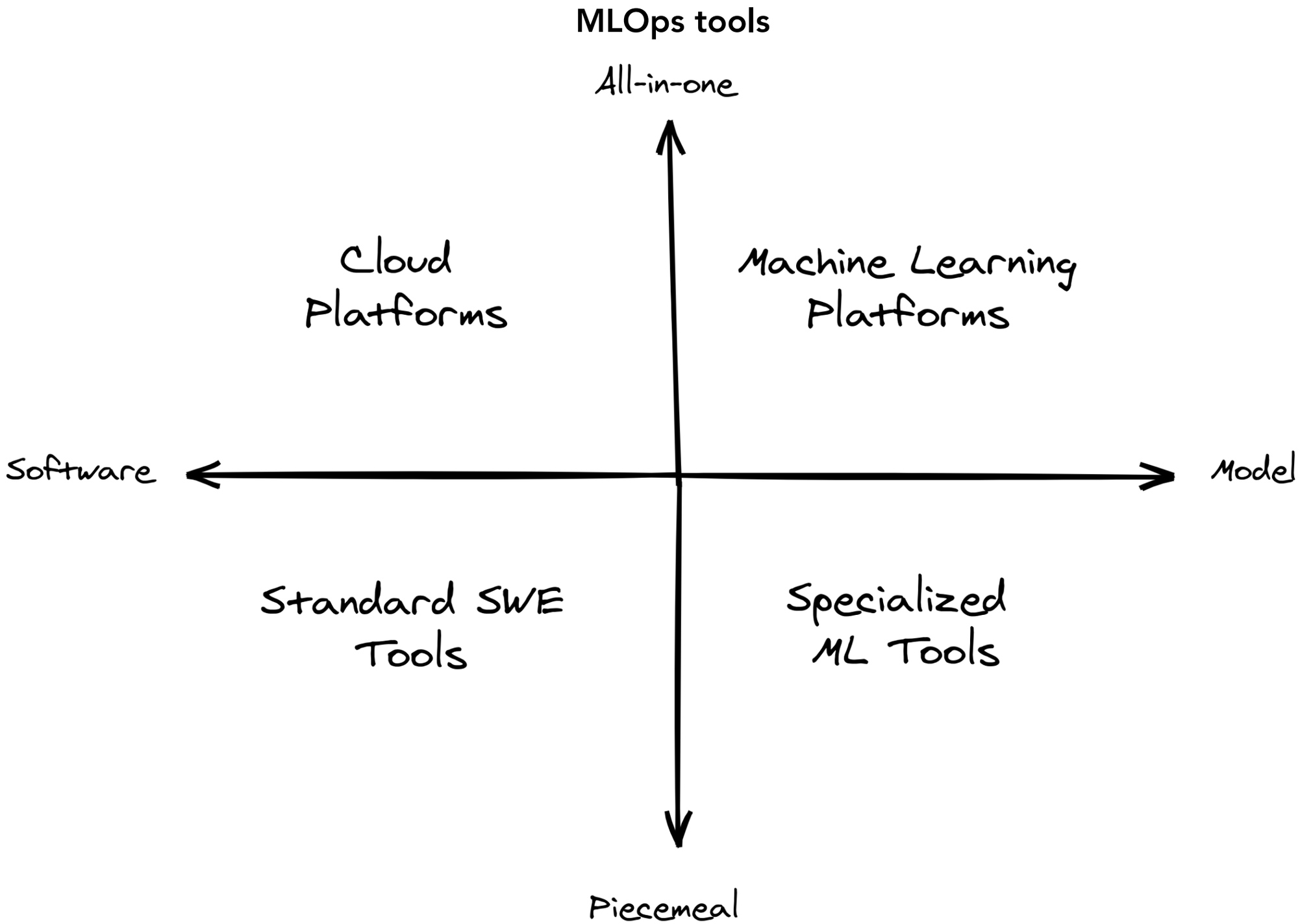
EARLY STAGE VENTURE CAPITAL

MLOps tools

MLOps Principles	Data	ML Model	Code
Versioning	1) Data preparation pipelines 2) Features store 3) Datasets 4) Metadata	1) ML model training pipeline 2) ML model (object) 3) Hyperparameters 4) Experiment tracking	1) Application code 2) Configurations
Testing	1) Data Validation (error detection) 2) Feature creation unit testing	1) Model specification is unit tested 2) ML model training pipeline is integration tested 3) ML model is validated before being operationalized 4) ML model staleness test (in production) 5) Testing ML model relevance and correctness 6) Testing non-functional requirements (security, fairness, interpretability)	1) Unit testing 2) Integration testing for the end-to-end pipeline
Automation	1) Data transformation 2) Feature creation and manipulation	1) Data engineering pipeline 2) ML model training pipeline 3) Hyperparameter/Parameter selection	1) ML model deployment with CI/CD 2) Application build
Reproducibility	1) Backup data 2) Data versioning 3) Extract metadata 4) Versioning of feature engineering	1) Hyperparameter tuning is identical between dev and prod 2) The order of features is the same 3) Ensemble learning: the combination of ML models is same 4)The model pseudo-code is documented	1) Versions of all dependencies in dev and prod are identical 2) Same technical stack for dev and production environments 3) Reproducing results by providing container images or virtual machines
Deployment	1) Feature store is used in dev and prod environments	1) Containerization of the ML stack 2) REST API 3) On-premise, cloud, or edge	1) On-premise, cloud, or edge
Monitoring	1) Data distribution changes (training vs. serving data) 2) Training vs serving features	1) ML model decay 2) Numerical stability 3) Computational performance of the ML model	1) Predictive quality of the application on serving data

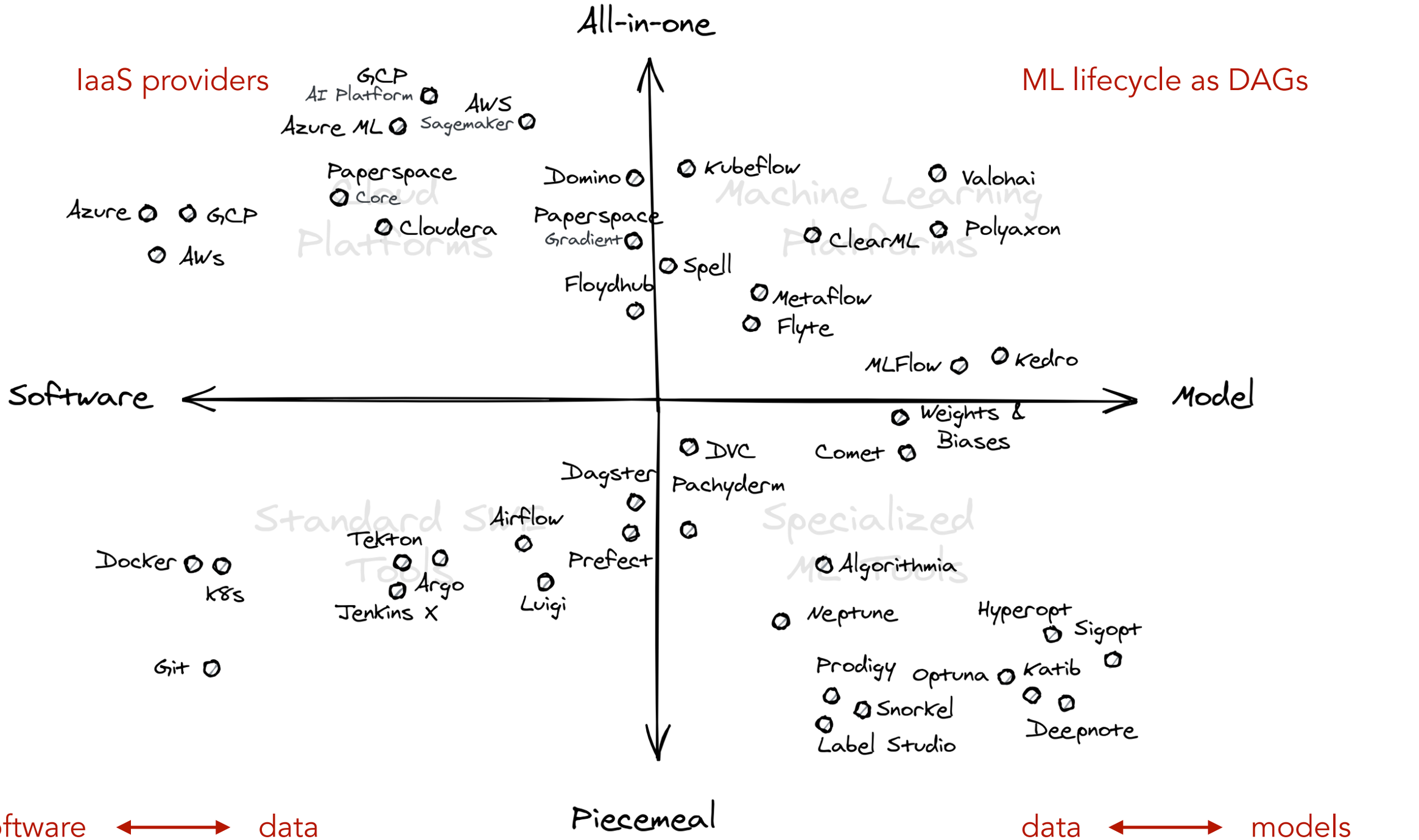
MLOps tools


Number of ML/AI tools (cumulative)
All-in-one
Data pipeline
Hardware
Infrastructure
Modeling & Training
Serving
0
50
100
150
200
250
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020



x-axis: artifact
y-axis: scope

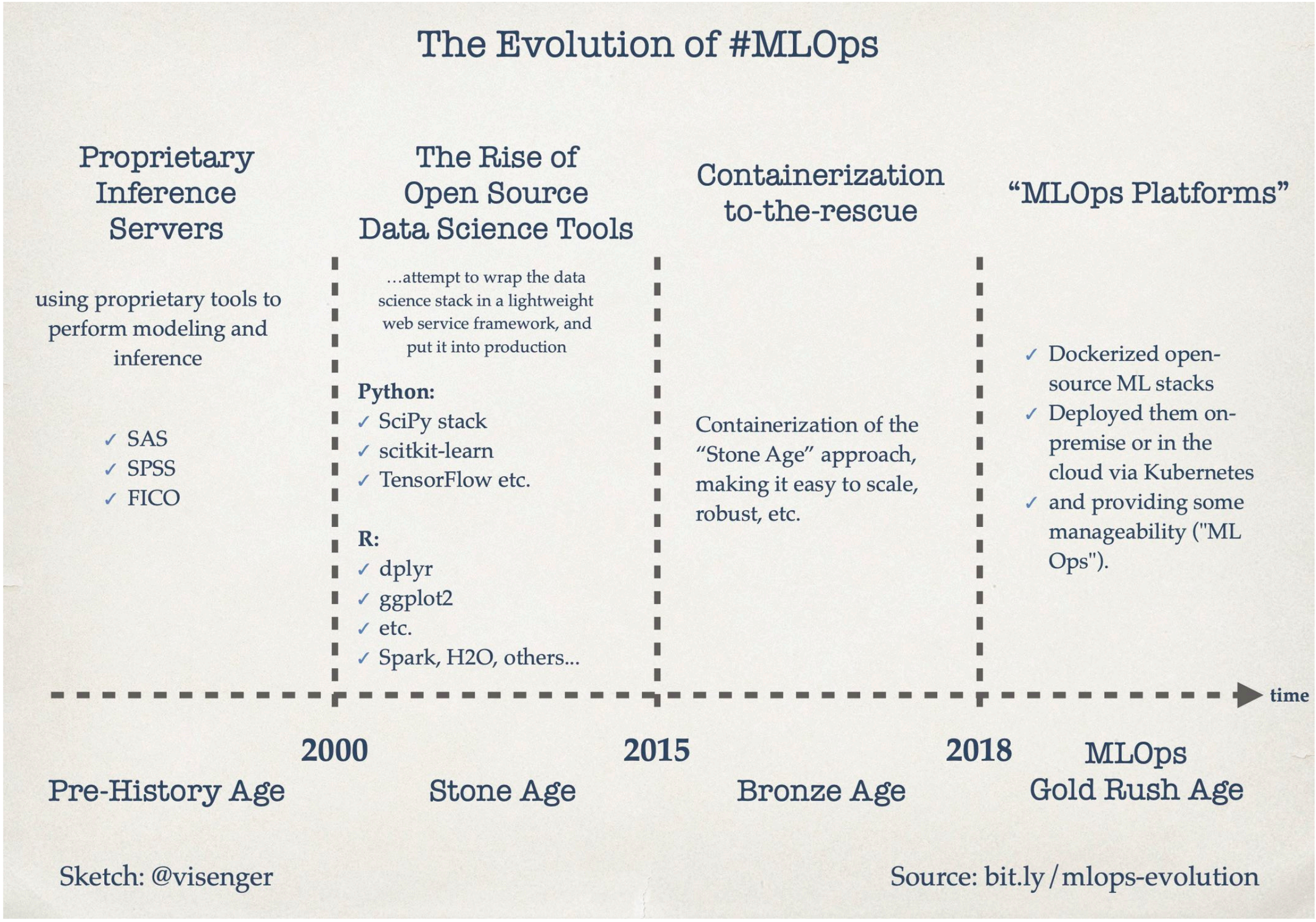
MLOps tools



x-axis: artifact

y-axis: scope

Predictions



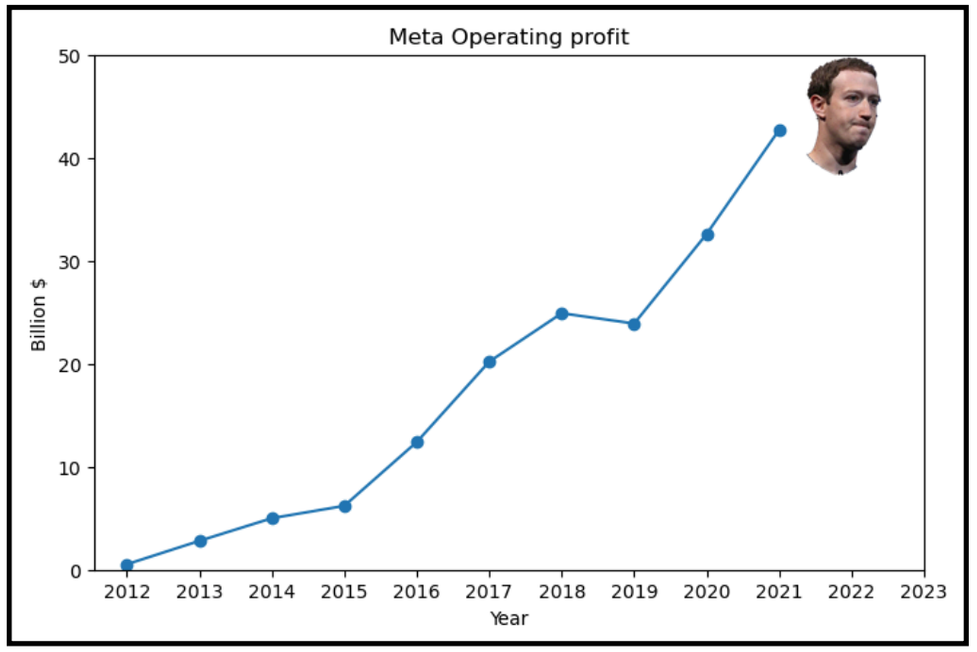
Signals from Big AI Companies

Signals from Big AI Companies

Layoffs

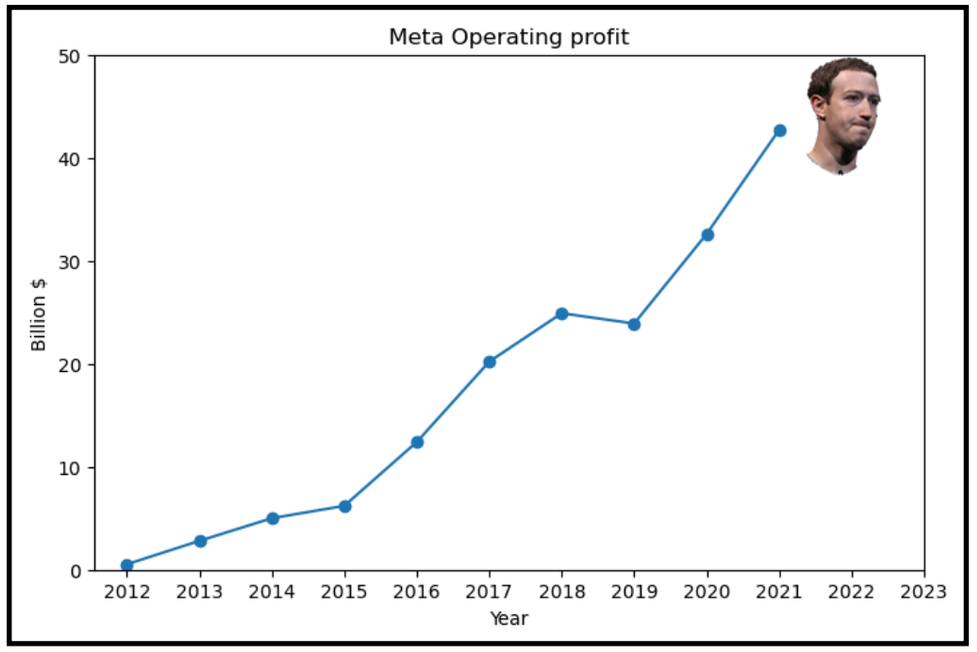
Signals from Big AI Companies

Layoffs



Signals from Big AI Companies

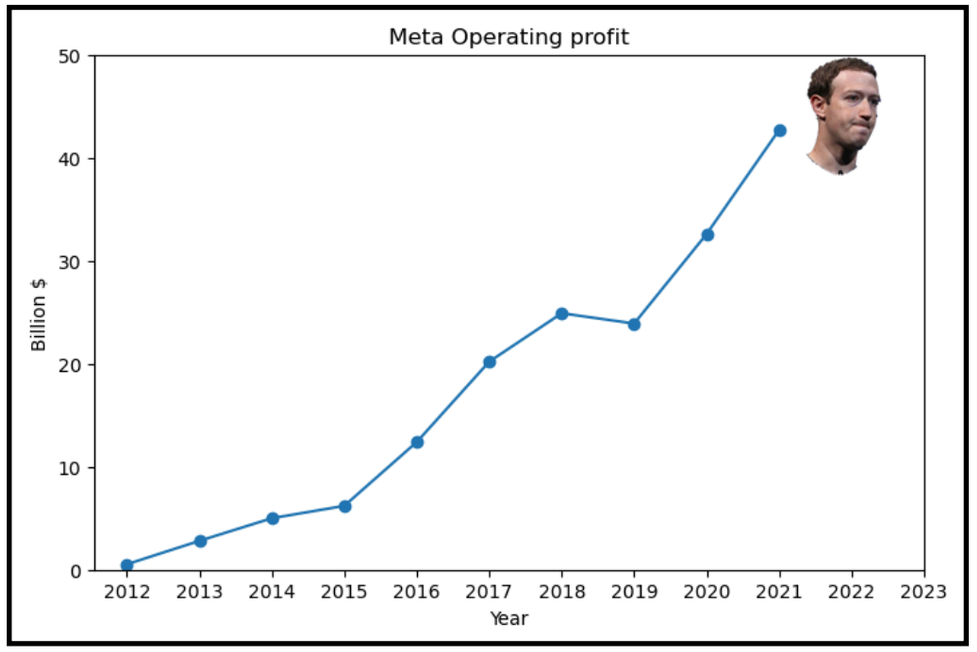
Layoffs



Physical world's problems

Signals from Big AI Companies

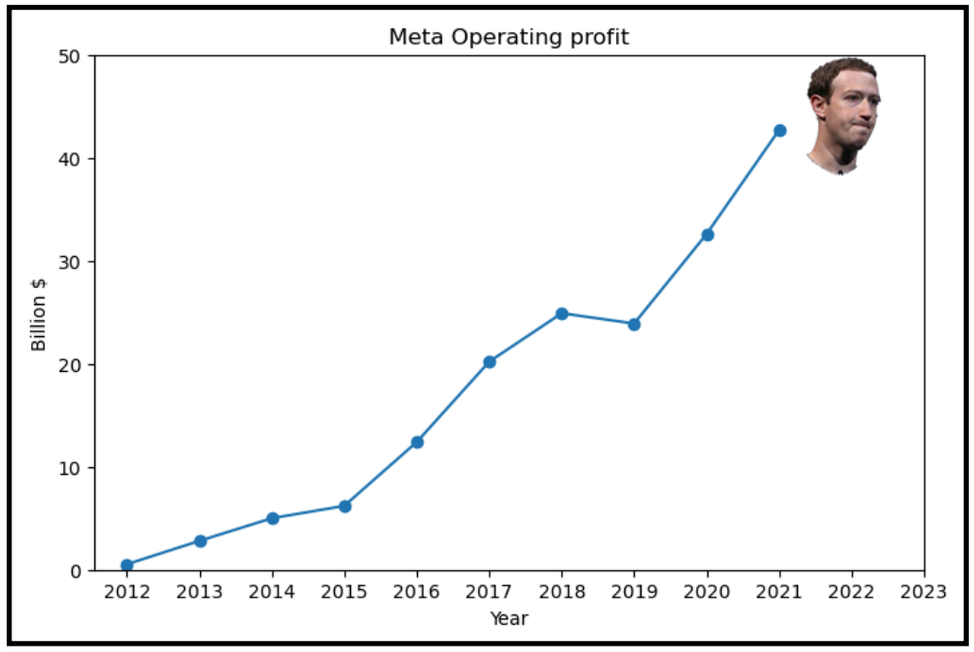
Layoffs



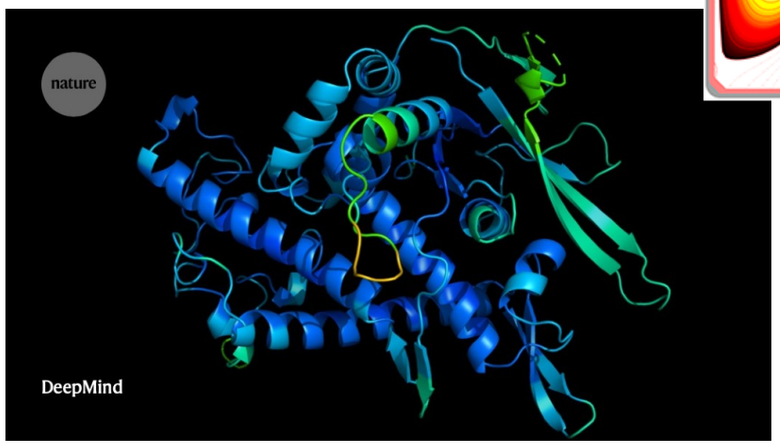
Physical world's problems

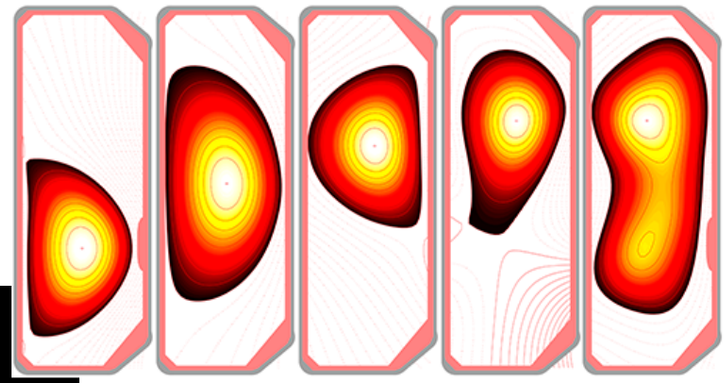
Signals from Big AI Companies

Layoffs



Physical world's problems





Prediction / Hope

Prediction / Hope

MLOps adoption and ease of use might allow different organisations (governments, research institutes, all type of companies) to deploy and use AI to **help solving or mitigating** some of the problems we're inevitably going to face in the next decades (food and energy scarcity, climate change damages)

Prediction / Hope

MLOps adoption and ease of use might allow different organisations (governments, research institutes, all type of companies) to deploy and use AI to **help solving or mitigating** some of the problems we're inevitably going to face in the next decades (food and energy scarcity, climate change damages)

And we might realise that maybe AI was never meant to be used for generating profits or controlling people using recommended ads and customer behaviour profiling **but to solve real problems in the physical world**

References

Books :

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