Agenda

1. Learning goals

2. Challenges and motivation

3. ML and MLOps

   a. How does ML differ from traditional SW development?

   b. Towards MLOps: first Reference Architecture

   c. Approach in FIWARE

4. Summary, resources, exercises & QA

22-23 May, 2025 | Rabat Smart City, Morocco

#FIWARESummit25

FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY
FIWARE   UM6P

Agenda

1. **Learning goals**

2. Challenges and motivation

3. ML and MLOps

   a. How does ML differ from traditional SW development?

   b. Towards MLOps: first Reference Architecture

   c. Approach in FIWARE

4. Summary, resources, exercises & QA

Learning Goals

- ML cycle: differences with typical SW development

- MLOps: what is it?

    □ The MLOps life cycle

    □ Integration in FIWARE

- Implement in FIWARE solutions

    □ Definition of SDM

    □ Pipeline for deploying and performing inference

FIWARE Global Summit | Rabat Smart City PART OF Smart Cities Morocco Roadshow 2025 ORGANIZED BY FIWARE UM6P

Agenda

1. Learning goals

2. **Challenges and motivation**

3. ML and MLOps

   a. How does ML differ from traditional SW development?

   b. Towards MLOps: first Reference Architecture

   c. Approach in FIWARE

4. Summary, resources, exercises & QA

FIWARE Global Summit

Rabat Smart City

PART OF Smart Cities Morocco Roadshow 2025

ORGANIZED BY FIWARE UM6P

Challenges and motivation

Motivation:

- Context-driven automation: use the Context Broker to kick different stages of the MLOps process
- Unified context and Observability: the metadata of ML and its operation live in the same context graph as the data, gaining explainability
- Interoperability and Reusability: any ML artifact can be discovered and reused
- Standardized Metadata via SDM: Anyone and any service will exactly know what `model.version` is or how to interpret `job.status`
- Event-based MLOps pipelines: the flow of actions is naturally triggered by the nature of the FIWARE system, guided by subscription/notification mechanism
- Decoupled microservised-friendly design: each ML and MLOps subsystem subscribes to specific NGSI-LD entities, making the system easy to change when needed

FIWARE Global Summit

Rabat Smart City

PART OF Smart Cities Morocco Roadshow 2025

ORGANIZED BY FIWARE UM6P

Challenges and motivation

Challenges:

- Data modelling complexity: this SDM definition can be non-trivial and as complex and granular as wanted. Important to manage the level of detail
- Trigger-Orchestration semantic and complexity: extra thing to take into account, ensuring that subscriptions are properly triggered, with the proper throttling and avoiding race conditions in case of chained multiple subscriptions
- State managing and versioning could fastly became chaotic and excessive complex
- Security and Data Governance: when it comes to sensitive data, as ML models, need to keep an eye to security, adding a point of complexity
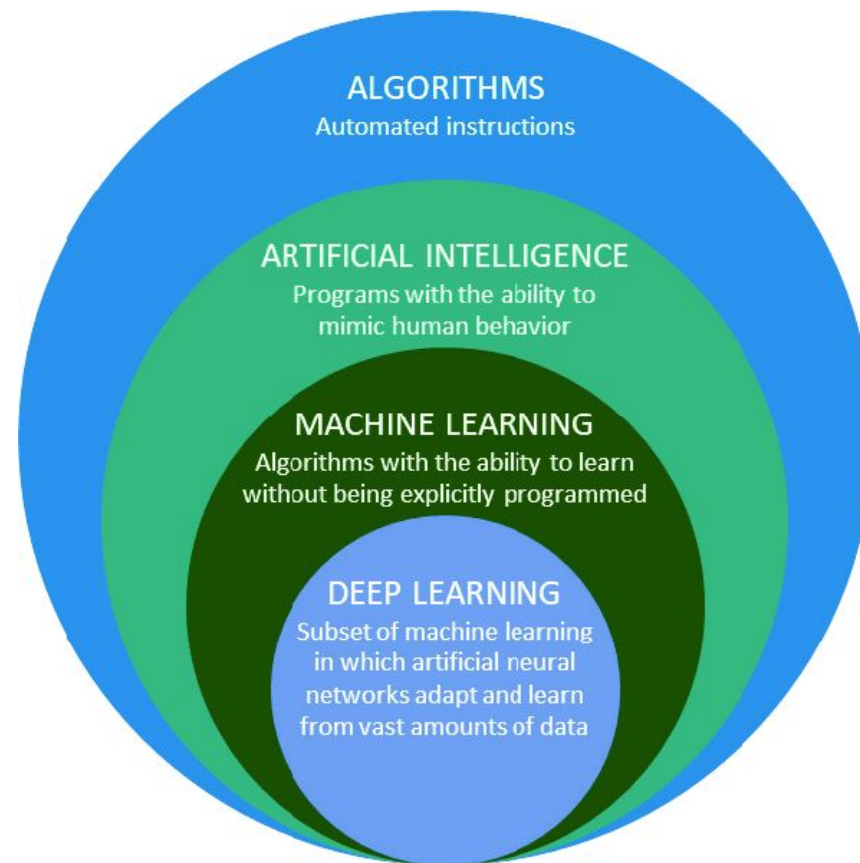
FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities Morocco Roadshow
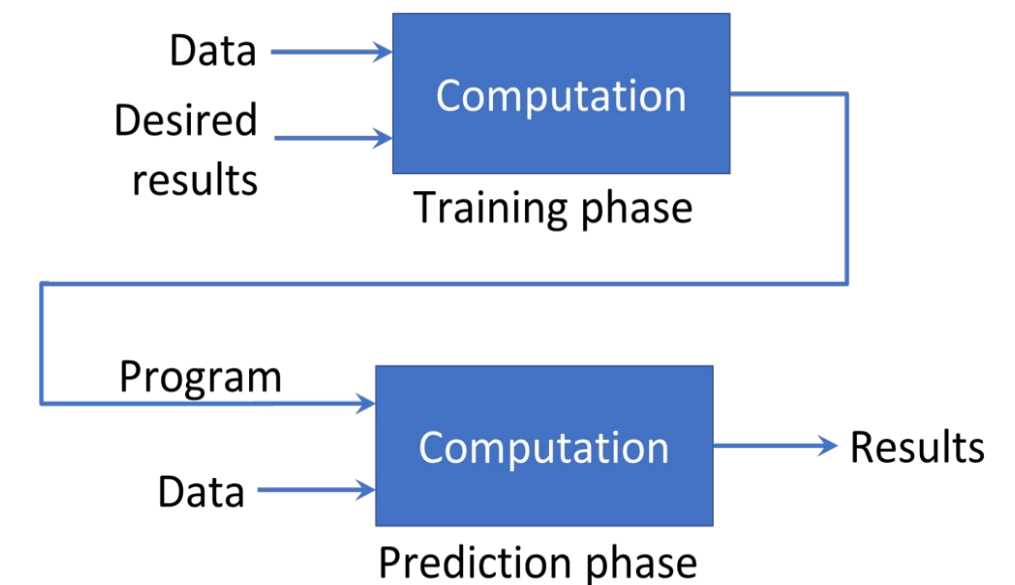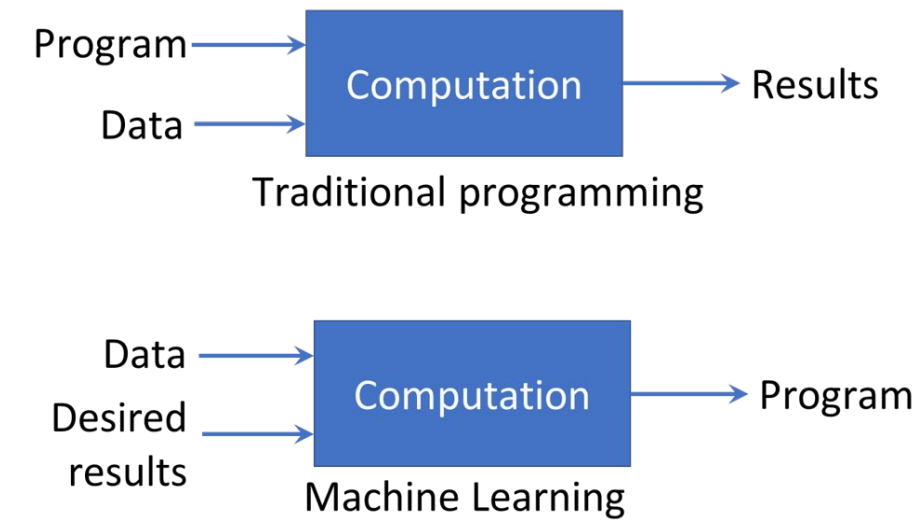2025

ORGANIZED BY
FIWARE UM6P

Agenda

1. Learning goals

2. Challenges and motivation

3. **ML and MLOps**

   a. How does ML differ from traditional SW development?

   b. Towards MLOps: first Reference Architecture

   c. Approach in FIWARE

4. Summary, resources, exercises & QA

22-23 May, 2025 | Rabat Smart City, Morocco

#FIWARESummit25

FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY

FIWARE   UM6P

ML and MLOps

The simplest machine learning pipeline is:

- train data and produce a model
- deploy the model and make inference

Automatizing the solution: Towards MLOps
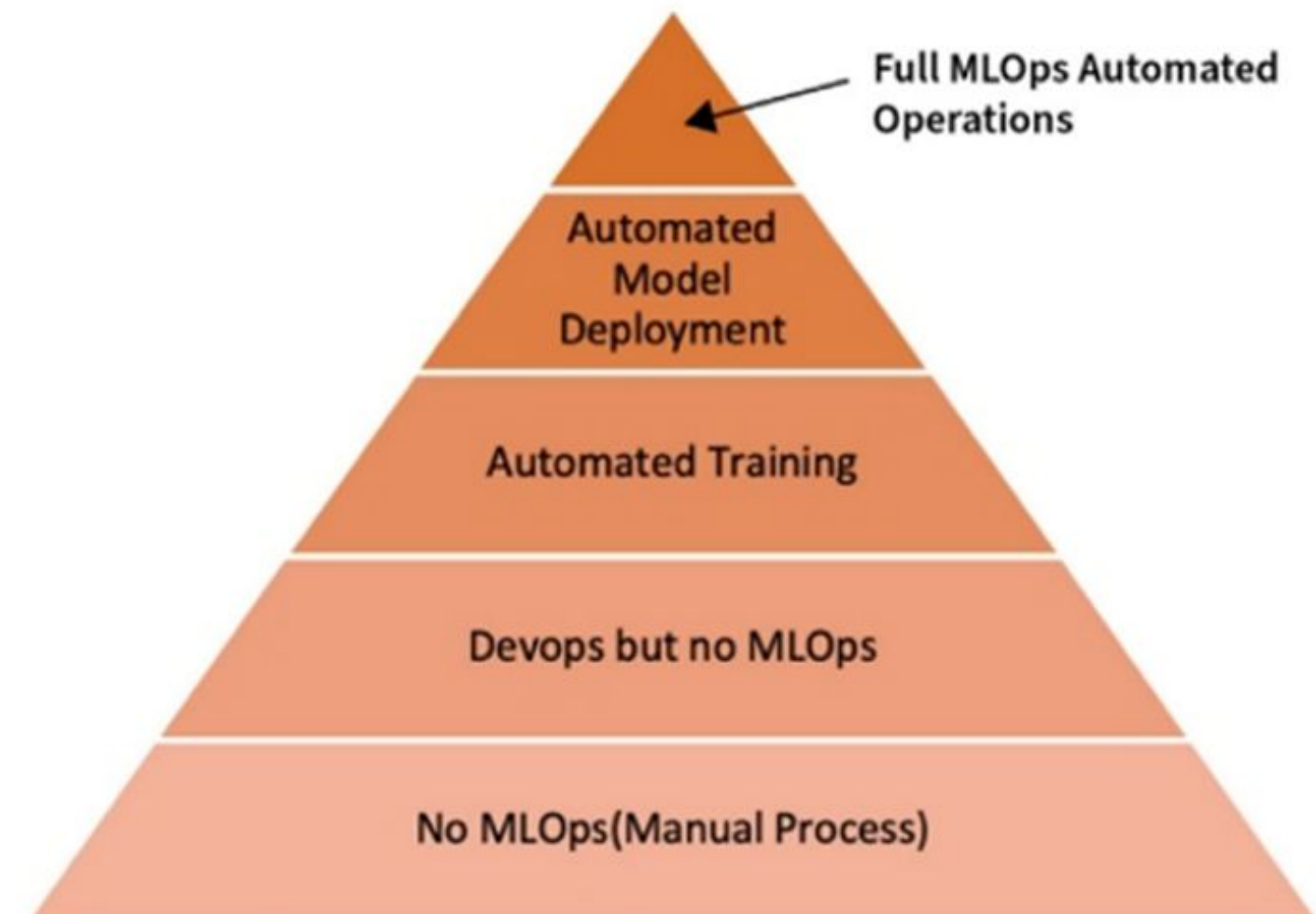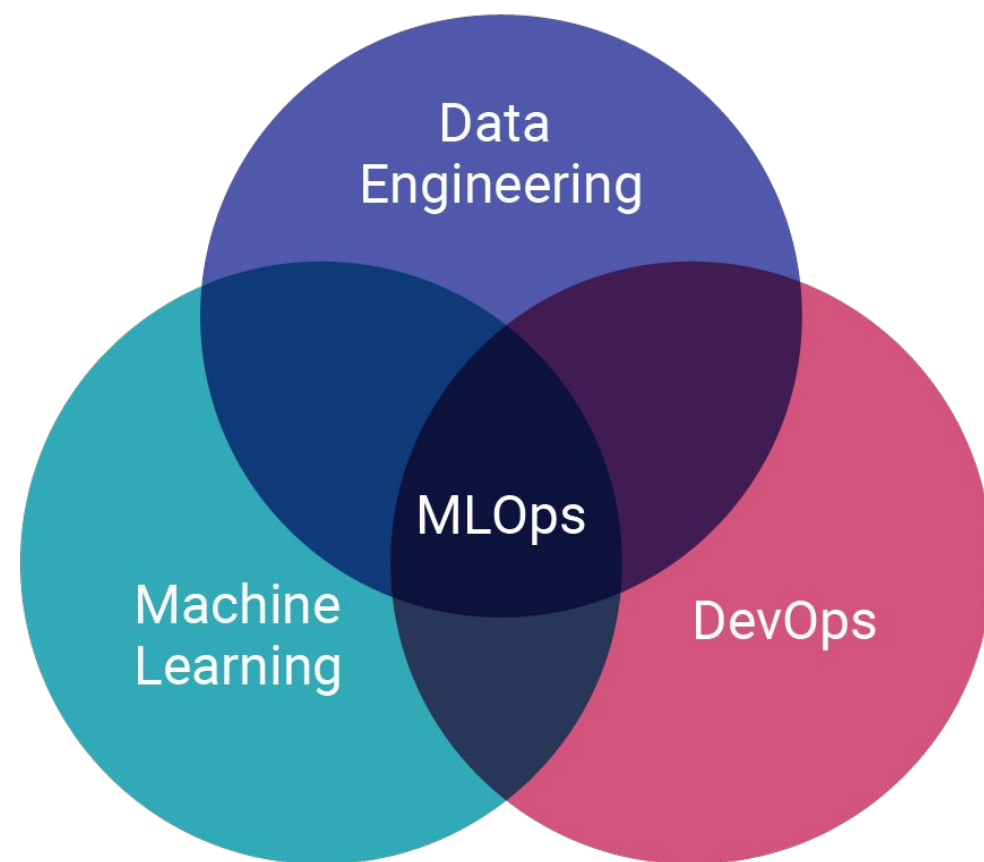
Full MLOps Automated Operations

Automated Model Deployment

Automated Training

Devops but no MLOps

No MLOps(Manual Process)

22-23 May, 2025 | <u>Rabat Smart City, Morocco</u>

#FIWARESummit25

FIWARE **Global Summit** | Rabat Smart City | **PART OF** Smart Cities Morocco Roadshow **2025** | ORGANIZED BY FIWARE UM6P
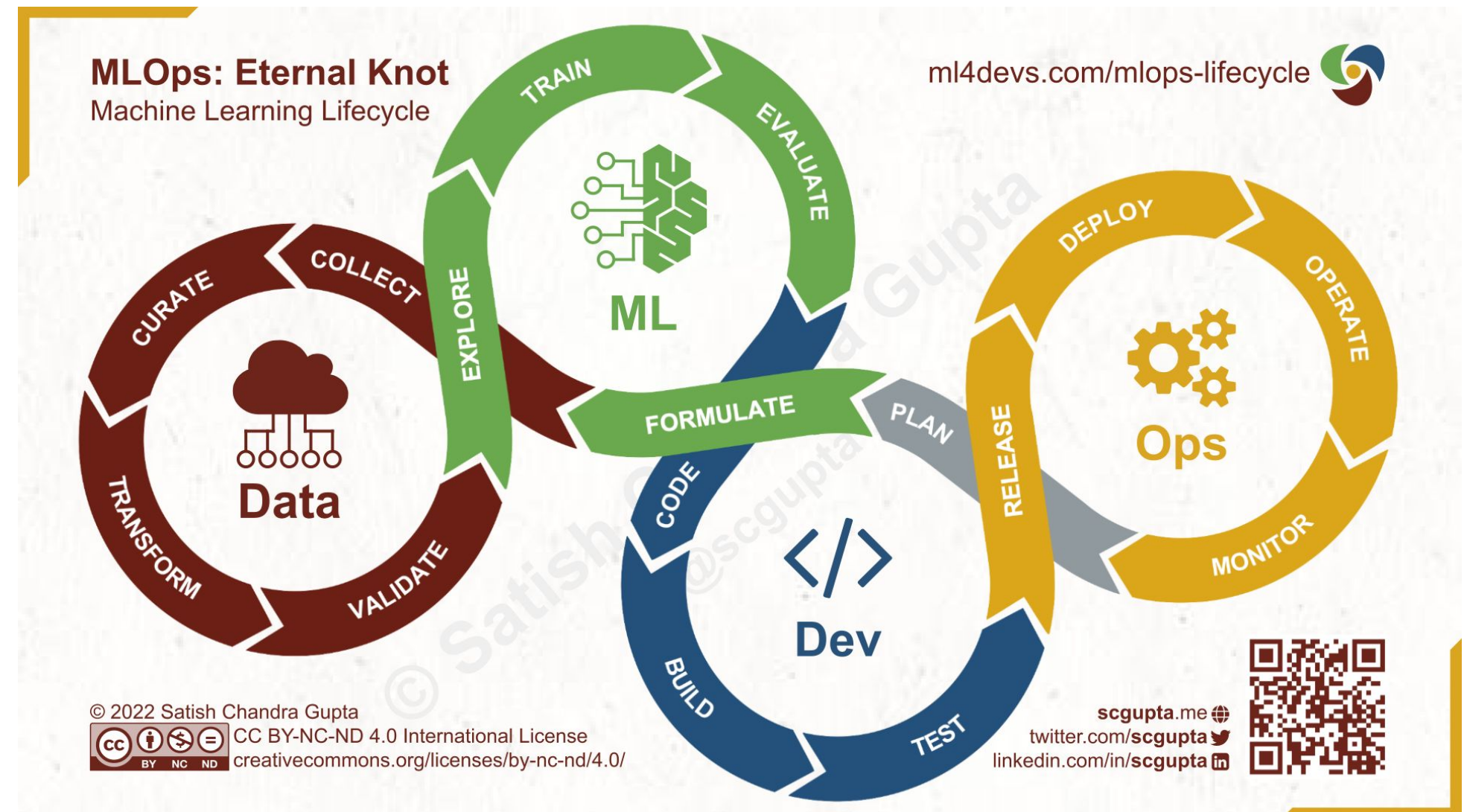
How to achieve MLOps: CRISP-ML

Need of a framework: CRISP-ML

1. Cross Industry Standard Process (CRISP) for Machine Learning
2. Proposed by Studer et al. in a paper in 2021(1)
3. It is a methodology specifically designed for guiding machine learning projects.
4. The process consists of six phases: Business and Data Understanding, Data Preparation, Modeling, Evaluation, Deployment and Monitoring and Maintenance.

MLOps: Eternal Knot
Machine Learning Lifecycle

ml4devs.com/mlops-lifecycle

ML — TRAIN, EVALUATE, EXPLORE, FORMULATE

Data — CURATE, COLLECT, TRANSFORM, VALIDATE

Dev — CODE, BUILD, TEST, PLAN

Ops — DEPLOY, OPERATE, RELEASE, MONITOR

© 2022 Satish Chandra Gupta
CC BY-NC-ND 4.0 International License
creativecommons.org/licenses/by-nc-nd/4.0/

scgupta.me
twitter.com/scgupta
linkedin.com/in/scgupta

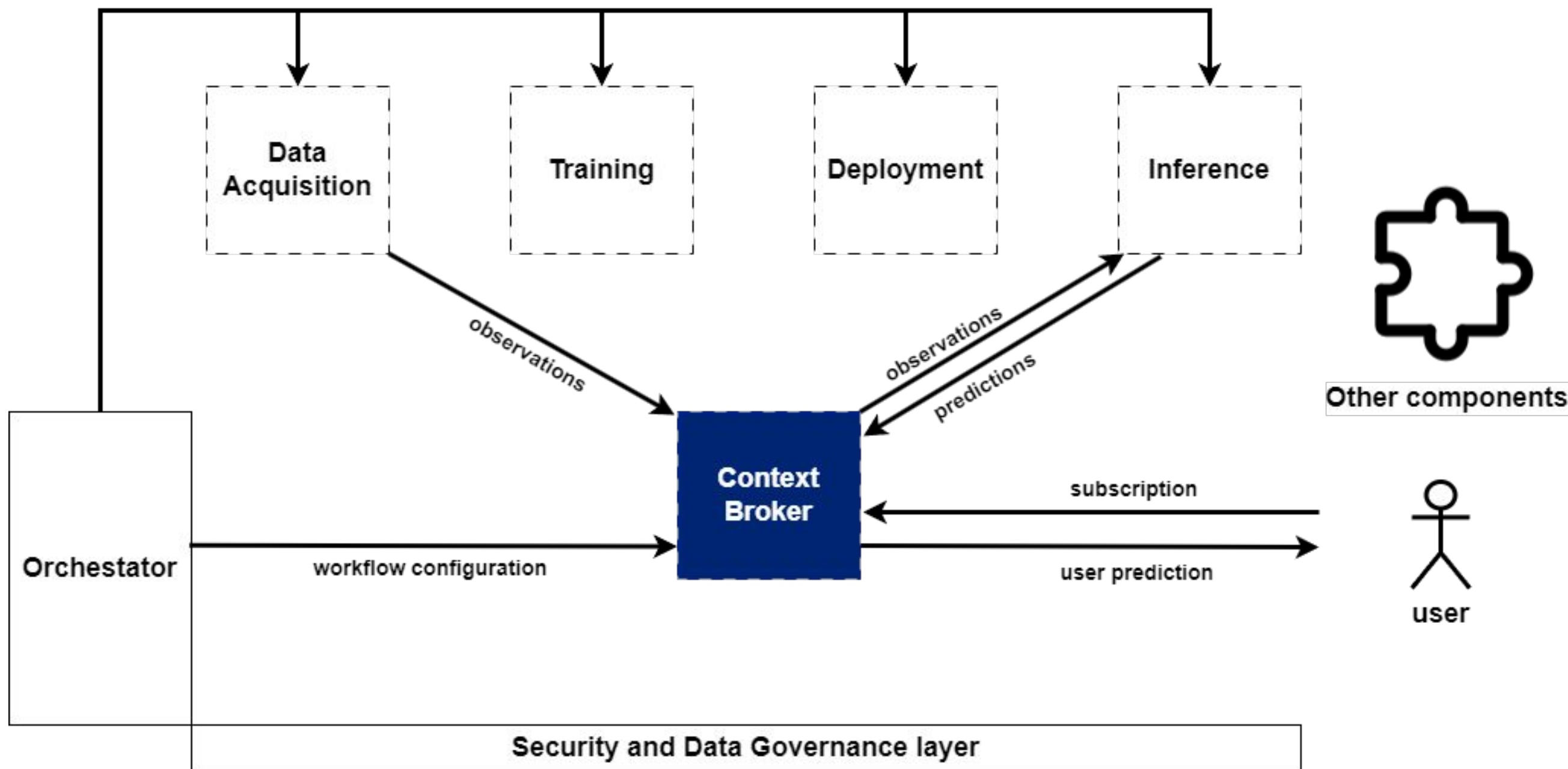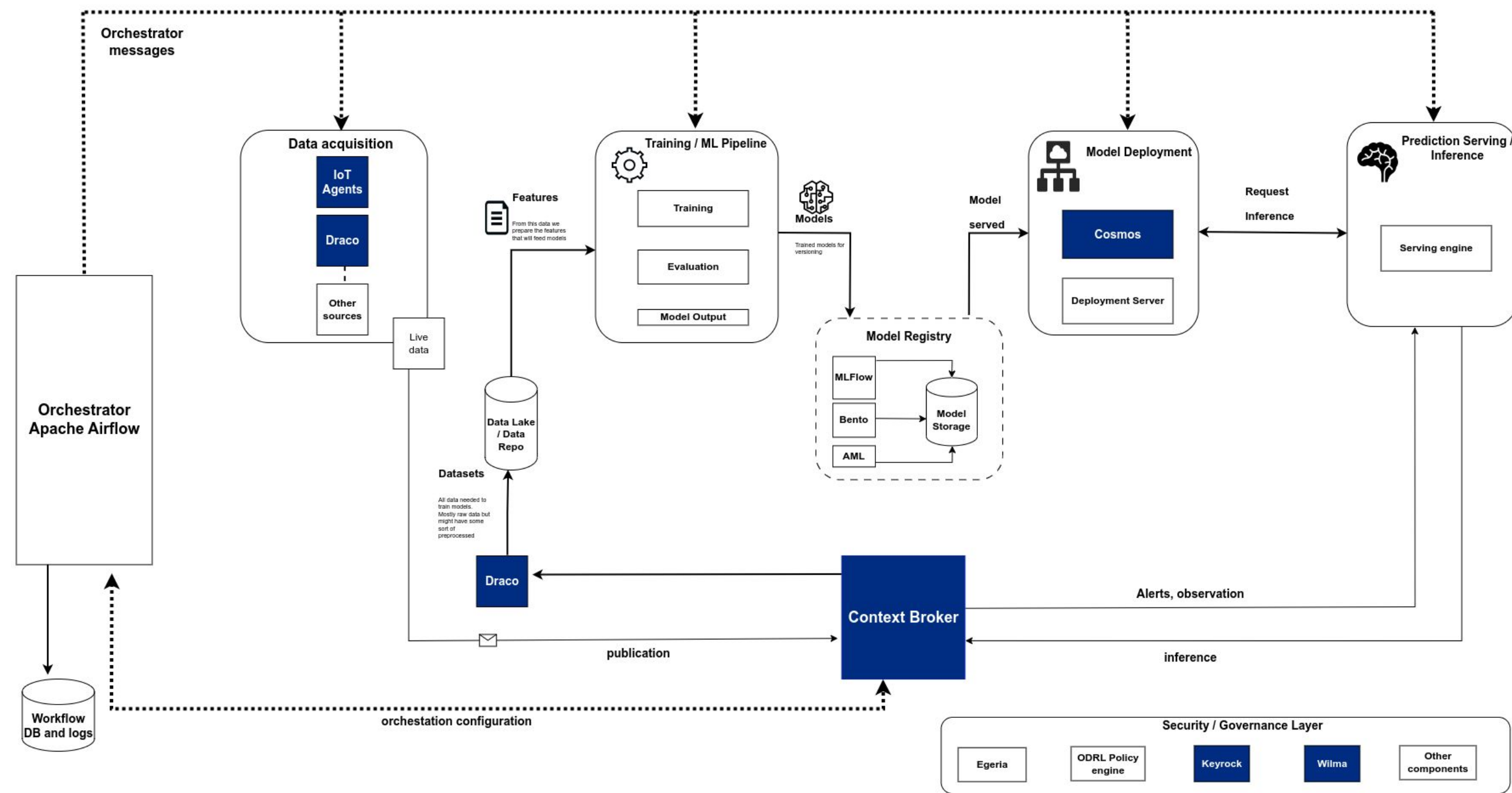FIWARE Global Summit | Rabat Smart City | PART OF Smart Cities Morocco Roadshow 2025 | ORGANIZED BY FIWARE | UM6P

FIWARE approach to MLOps

MLOps FIWARE RA

Integration in FIWARE: entities and subscriptions

Entities:

MLModel: describes the model, how was trained, dataset used, algorithm, accuracy, etc.

MLProcessing: It links 3 elements:

1. The ML model to be used for the processing
2. The data that the ML model will subscribe to
3. The entity where the ML model will store the result(s) of the processing

Subscriptions:

SubscriptionQuery:

- Inform when there is an attribute update (i.e. when a new inference should be done)
- Inform when there is a prediction update

FIWARE Global Summit

Rabat Smart City

PART OF Smart Cities Morocco Roadshow 2025

ORGANIZED BY FIWARE UM6P

Digit recognition example

http://localhost:5001/predict

Draw & Predict!

Select Model: [Mock model by default ▾] Default mock model loaded

Clear   Predict Digit

FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY
FIWARE   UM6P

Integration in FIWARE: entities and subscriptions

- **MLModel Entity**

```
{
  "id":"urn:ngsi-ld:MLModel:01",
  "type":"MLModel",
  "name": "Handwriting digit predictor",
  "description": "Given an image path, predicts the
digit represented…",
  "dockerImage": "Docker image containing the model",
  "algorithm": "CNN",
  "version": 12,
  "inputAttributes": ["imgPath", "size", "color"],
  "outputAttributes": ["predictionClass", "confidence"]
}
```

- It describes the model, how it works, what the input and output are

FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY

FIWARE

UM6P

Integration in FIWARE: entities and subscriptions

- **MLProcessing Entity**

```
{
  "id":"urn:ngsi-ld:MLProcessing:01",
  "type":"MLProcessing",
  "refMLModel": "urn:ngsi-ld:MLModel:01",
  "refSubscriptionQuery": "urn:ngsi-ld:SubscriptionQuery:01",
  "@context": [
"https://raw.githubusercontent.com/smart-data-models/dataModel
.MachineLearning/master/context.jsonld"
  }
}
```

- It relates three key elements:
  - The MLModel used to perform inference (who)
  - The data that el MLModel subscribes to process (what)
  - The entity where the MLModel will store the result(s) (where)

The advantage of using a subscription is that we can use something flexible to express queries like "I want the ML model to process certain attributes <a1, a2, …, an> of an entity <T1> that fulfill certain requirements <r1, r2, …, rk> (e.g. created by certain user, located in specific area, etc.)

Integration in FIWARE: entities and subscriptions

- **SubscriptionQuery - Inform about**

```
{
  "id": "urn:ngsi-ld:Subscription:01",
  "type": "SubscriptionQuery",
  "entities": [
    {
      "type": "HandwritingDigit"
    }
  ],
  "notification": {
    "attributes": [
      "imagePath",
      "imageMetadata"...
    ],
    "format": "keyValues",
    "endpoint": {
      "uri": "http://my-domain-name",
      "accept": "application/json"
    }
  },
```

```
  "q": "language==urn:ngsi-ld:lang:Spanish",
  "watchedAttributes": [
    "predictedDigit",
    "confidence"
  ],
  "@context": [

"https://raw.githubusercontent.com/smart-data-models/dataMo
del.MachineLearning/master/context.jsonld"
  ]
}
```

FIWARE Global Summit

Rabat Smart City

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY
FIWARE UM6P

A typical ad-hoc ML pipeline

- **Data Scientist**

  - Get and clean up data
  - Prepare and train a ML model

- **IT person (deployment service)**

  - Package and deploy the ML model

- **End user / service**

  - Discover the available ML models (with respect to privacy)
  - Ask to use one or more of them (and optionally pay for it)
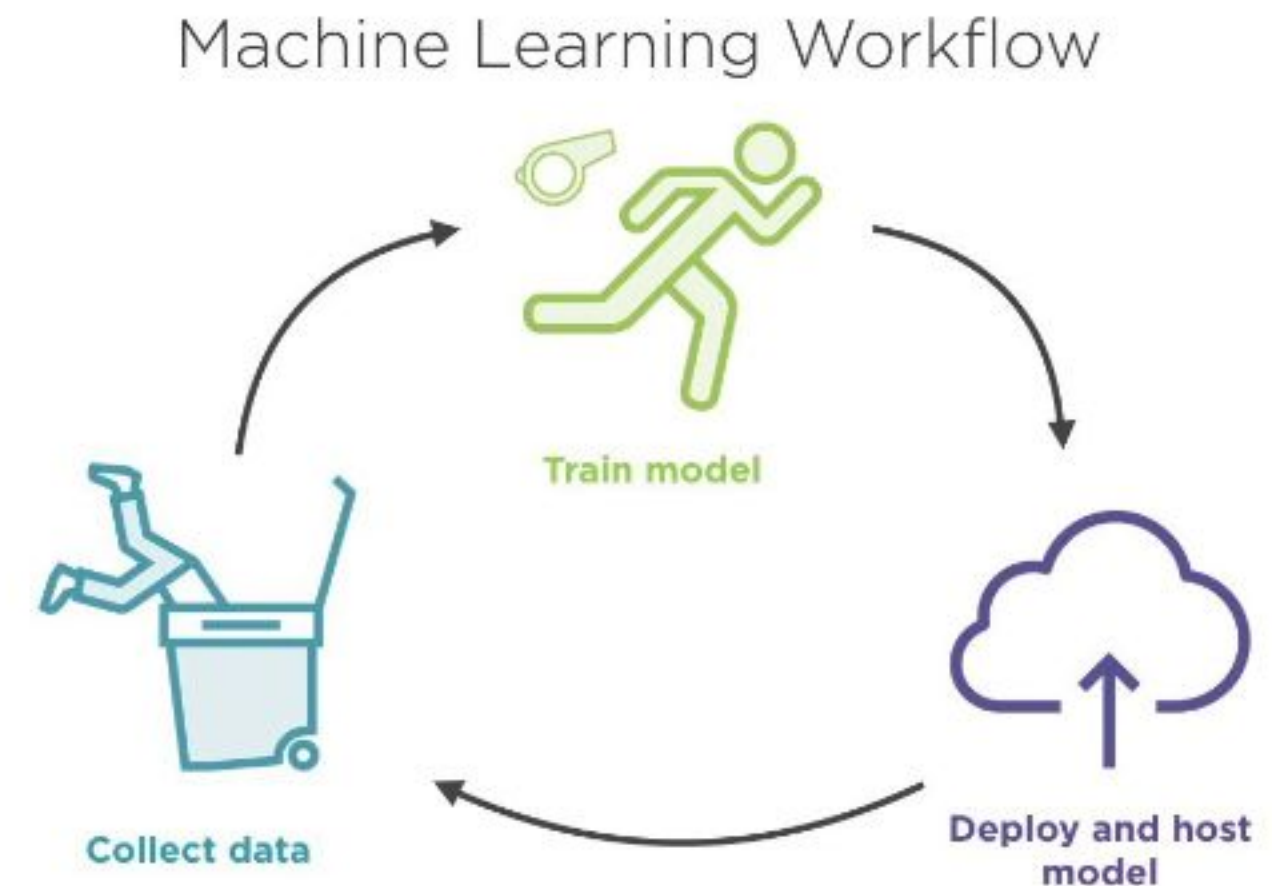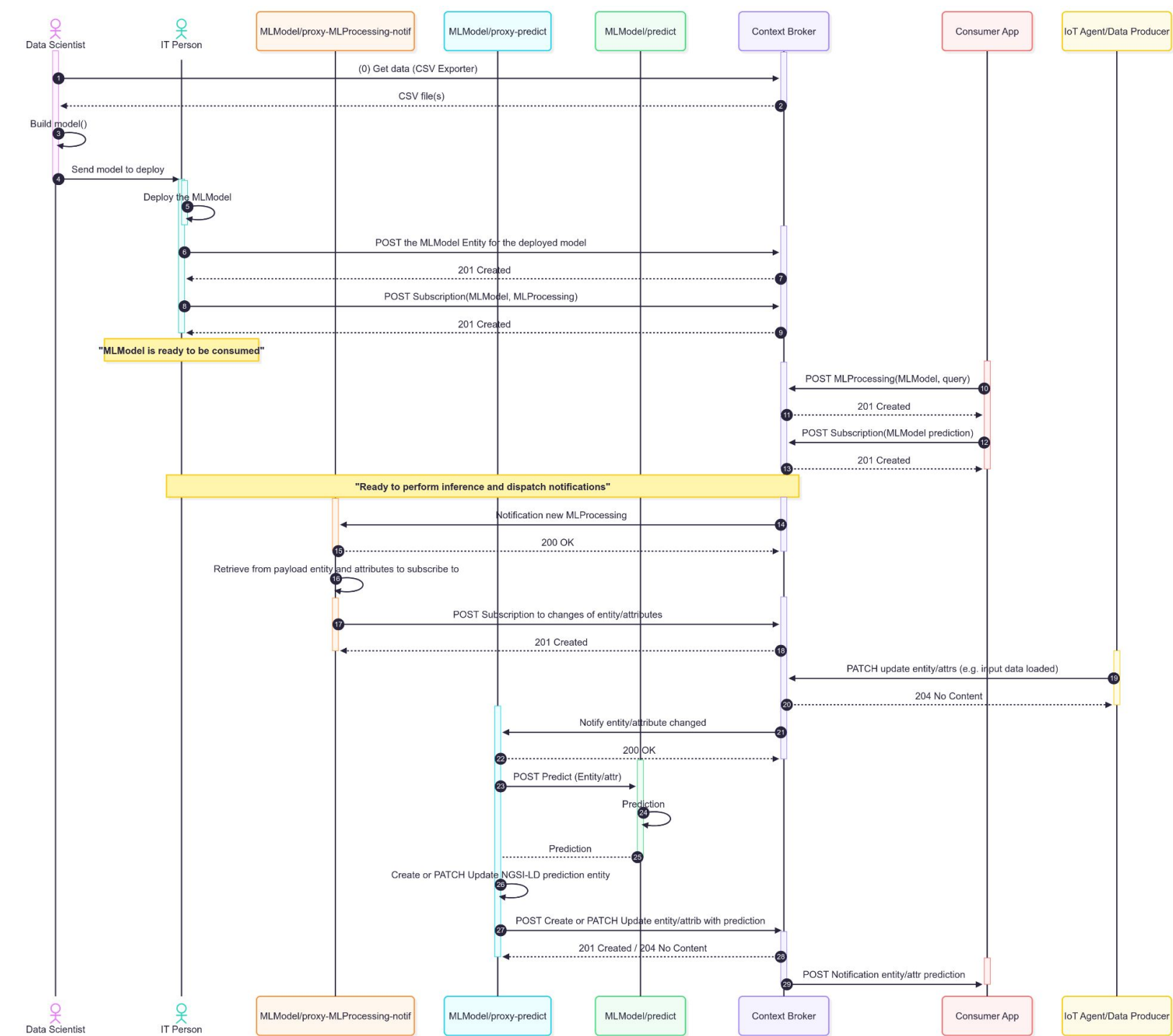 - Get real time data (predictions, outliers,...) from a ML model

Machine Learning Workflow

Train model

Deploy and host model

Collect data

Image taken from here

FIWARE Global Summit

Rabat Smart City

PART OF Smart Cities Morocco Roadshow 2025

ORGANIZED BY FIWARE UM6P

Integration in FIWARE

Agenda

1. Learning goals

2. Challenges and motivation

3. ML and MLOps

   a. How does ML differ from traditional SW development?

   b. Towards MLOps: first Reference Architecture

   c. Approach in FIWARE

4. **Summary, resources, exercises & QA**

FIWARE Global Summit | Rabat Smart City | PART OF Smart Cities Morocco Roadshow 2025 | ORGANIZED BY FIWARE UM6P

Summary

- Described the ML and MLOps process and how differ from traditional SW dev.

- MLOps concepts description and how can be implemented using CRISP-ML methodology

- Proposed a reference architecture for integration of MLOps workflow in FIWARE solutions

- Described Smart Data Models for the characterization of ML deploying and inference process

- Set the basis of a possible workflow for performing MLaaS in FIWARE solutions (SDM and subscriptions)
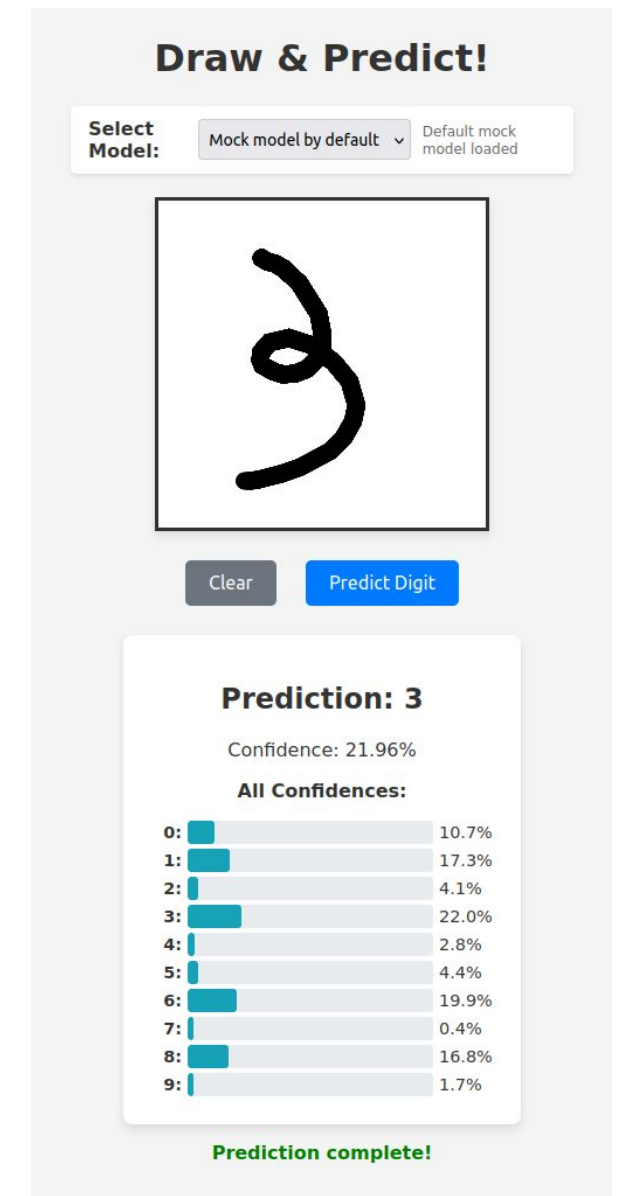
Resources

- Repository with code and slides:
  - https://github.com/dncampo/fgs2025-digit-recognizer-ml

- MLOps in FIWARE example:

  - Document architecture here.
  - FGS2024 example and slides: https://github.com/dncampo/FGS2024_ML-training/tree/main
  - Parking example using MLOps concepts: https://github.com/ging/fiware-mlops-parking

- MLOps maturity model from Microsoft, here

- CRISP-ML methodology

FIWARE Global Summit

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY
FIWARE   UM6P

Follow-up / exercises

- Please clone the repo https://github.com/dncampo/fgs2025-digit-recognizer-ml

- Run the app for prediction and send (HandwritenDigit) images, what happen? Could you check to against the CB if any entities are there? What is the entity type of these images?

- You will find a trained model...why aren't they used in the app under the /predict endpoint?

- How would you solve that? Implement the expected piece of code / entities to solve the issue

- Now you see a ML model, what do you need to produce some notification in a specific endpoint? Implement the necessary entity to send to the CB to receive the notification after a prediction

PART OF
Smart Cities Morocco Roadshow 2025

ORGANIZED BY
FIWARE UM6P

![FIWARE Global Summit]

Hosting Partner

UM6P
University Mohammed VI Polytechnic

Sponsors

bizztech

Latitudo40

Meaningfy

SenLab

Media Partners

BABLE

Club GLOBALS

IoTGN IoT GLOBAL NETWORK

IoTNOW HOW TO RUN AN IoT ENABLED BUSINESS

Smart Cities World

22-23 May, 2025 | Rabat Smart City, Morocco
#FIWARESummit25

FIWARE Global Summit

Rabat Smart City **R**

PART OF
Smart Cities
Morocco Roadshow
2025

ORGANIZED BY
FIWARE
UM6P