DDP

Docker Databases Pandas

Code and slides

- Slides and code snippets are also pushed to repositories on GitHub
https://github.com/Giulianini/docker-database-pandas

- Make a lot of questions (make me feel the Impostor Syndrome)
- Guideline:
    - Slides with "→ Example" refer to a practical example on notebook or shell
    - All the "floating code" in slides is present in the form of script.sh inside corresponding folders. Ex docker-intro/scripts/docker-run.sh
- Examples:
    - 1 Real example of a sample project → REST API – Controller – Model (DBs)
    - More notebook examples of pandas-database interactions
    - Docker is used in each example, be comfortable with it
- Tools: Beekeper (portable) , Postman , MongoDB Compass

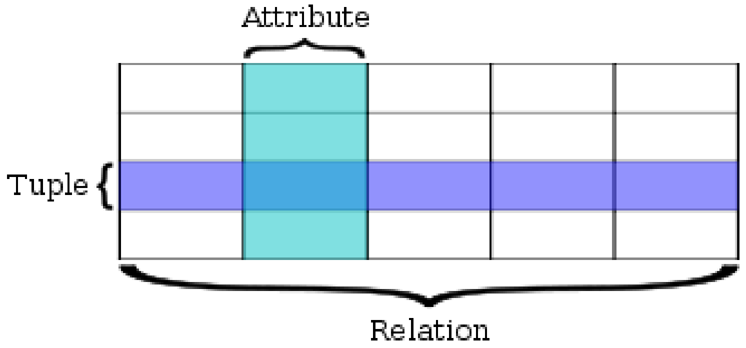
Schedule

- ~~Docker refresh~~
  - ~~Theory~~
  - ~~Docker commands~~
  - ~~Dockerfile~~
  - ~~Docker compose~~
- Databases
  - Relational – SQL like → MYSQL, SQLServer, Oracle
  - Object-Relational – SQL Like → PostgreSQL
  - Non-Relational – NoSQL like → MongoDB
  - Temporal – SQL like (custom syntax) → InfluxDB
- Pandas integration → Probably shown in parallel with each DB type

Relational DBs - RDBMS

- **First type DB** (1970) created by IBM: used since that time, pervasive systems
- Data organization with an OOP perspective:
  - **Tables:** relations of columns and rows with a unique **id** for each row. *Like **Classes** in OOP*
    - → **Type of Entity** (Person, Customer, ecc)
  - **Column:** attributes of the type. *Like **fields** in OOP languages*
  - **Row:** tuples, records of multiple attributes of same relation. *An **instance of a Class** in OOP*
  - ***Keys:***
    - *each instance must be unique and identified by the **smallest set of attributes**→ **Primary Key***
    - *relations between **A** and **B** are created using the **primary key** of **B** inside **A. Foreign key***

- ***Modelling***
  - *We use the **Entity Relationship** model (ER) → like UML*
  - ***Entity**: the tables with attributes*
  - ***Relationship**: connection between keys*
    - ***1-1** → Person - Anagraphic*
    - ***1-*** → Person - Gadget*
    - ****-1** → Person - Bus*
    - ****-*** → Person - Course*



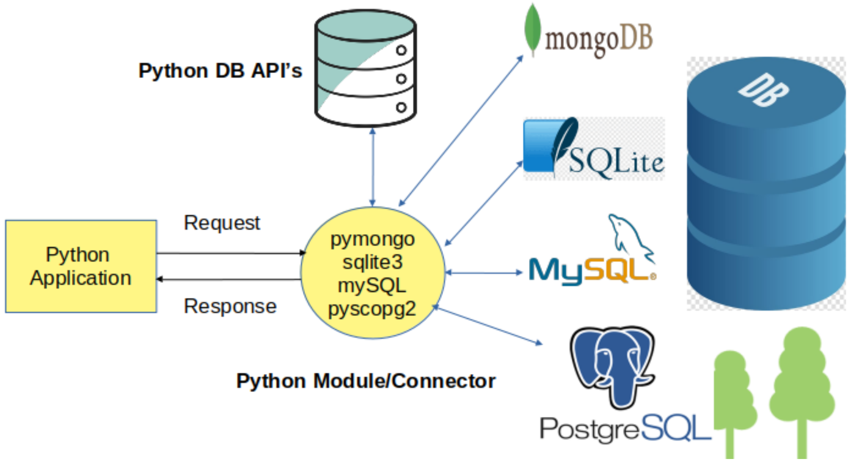
My SQL (SQL Like) – A Company-wise view

- **Commercial factors:**
  - **Most famous RDBMS**: client and server
  - Free software licensed under **GNU GPL** → **copyleft** not a business-friendly license. Company need to **release all source-code** to meet **GPL open-source transitive requirements!**
  - **Alternatives** → **MariaDB.** But licensed under **GPL** too!
  - **Totally free alternatives** → **SQL Lite** (**Public domain license**), **PostgreSQL** (**BSD license**), hence the fact that Postgres became the most used relational DB in the business world.
- **Servers (MySQL, Maria DB)**:
  - Working on port **3306 TCP**
  - Generally **self-hosted** but is sometimes present in *SAAS, PAAS* environments with preconfigured connectors.
  - Amazon AWS, Azure Database, ecc
  - **Dockerized** nature**:** simplify deployment, scaling, resource allocation, balancing.
- **Clients (Beekeeper):**
  - We use beekeeper to view database and make fast query.
  - Download the portable version

Databases and Python - Connection stack

- **The recipe for a DB connection in Python →** other languages behave in a similar way (Java JDBC)

1. **DB:** The DB itself. Communications happen through TCP connection.
2. **Connector:** A database connector is a **driver** that works like an **adapter** that connects a software interface to a specific database vendor implementation. Must Implement **DB API v2.0:**
    1. **PyMySQL → Our choice for MySQL connection**
    2. **MySQLdb →** MySQL
    3. **Psycopg2 →** PostgreSQL
    4. **SuperSQLite →** SQLLite



- **DB-API v2.0:** Python's standard database interface **specification** is **Python DB-API.** It's documented in PEP 249. Nearly all Python database connectors such as Sqlite3, PyMySQL, and MySQL-Python **conform** to this interface.

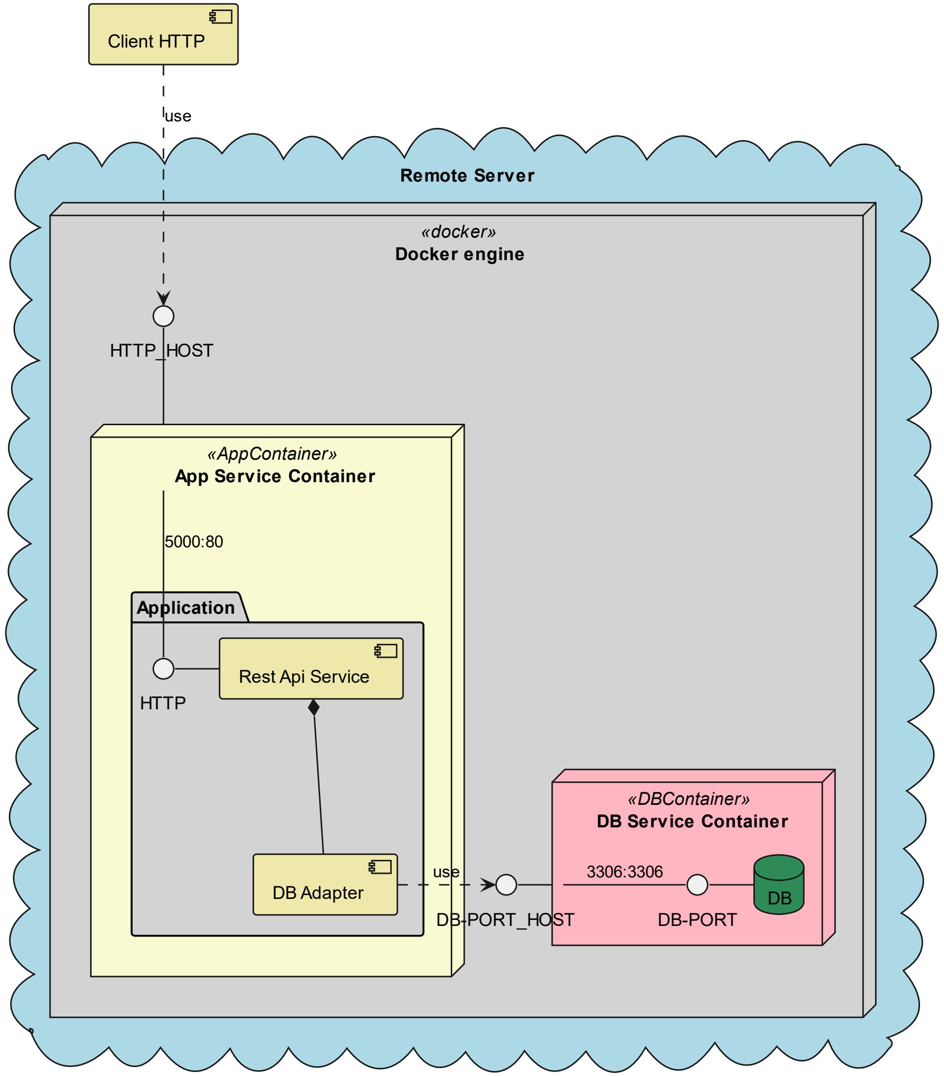
- **PyMySQL** is an interface for connecting to a MySQL database server from Python. It implements the Python Database API v2.0 and contains a pure-Python MySQL client library.

3. **SQLAlchemy**: A **Python SQL toolkit** and **Object Relational Mapper (ORM)** that gives application developers the full power and flexibility of SQL. SQLAlchemy supports many **dialects/DBAPI** options.

Rest API Service – SQL version → Example

- Multi service dockerization and internal connection
- **App Service Container:**
  - **REST API:** It's a Flask REST API server listening on localhost:80. See Dockerfile entrypoint.
  - **DB adapter:** it's a python module that maps REST method to SQL Queries. Queries are made using SQLAlchemy with pyMySQL connector driver.
  - **Mapping:** port 80 is mapped to 5000 on the host network because port 80 was already in use
  - **DB connection:** App service connects to the DB service using Docker internal DNS naming resolution. `sql-service→172.0.0.3`
  - **Restart on failure:** ***initially a connection error is raised because DB container is not completely initialized.***
- **DB Service Container**
  - **MySQL:** server listening on port 3306. No need for a remapping.
  - **Initialization:** tables initialized from init.sql script
  - **Configuration:** loaded from environment variables.
    - From **dotenv file** if outside docker
    - Passed to **docker-compose env-file** if inside docker

- **Exercise:** Add other REST-API and update DB accordingly → Test with Postman



MySQL - Pandas Integration → Example

- SQLAlchemy introduces **extension methods** for DB interactions: `to_sql e read_sql`
- **DB configuration**

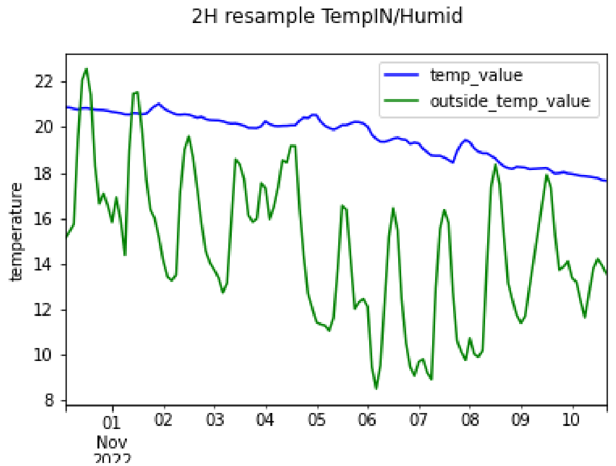
1. Install pymysql driver and sqlalchemy db tool
2. Database connection string with pymysql driver
3. Engine creation and connection

- **Reading cvs from Pandas**
  - Dataframe creation
- **Writing dataframe to SQL table**
  - Using sqlalchemy extension methods
- **Updating tables connections**
  - Need to remap Primary Key
  - Need to remap Foreign key
- **Execute sql query directly on DB**

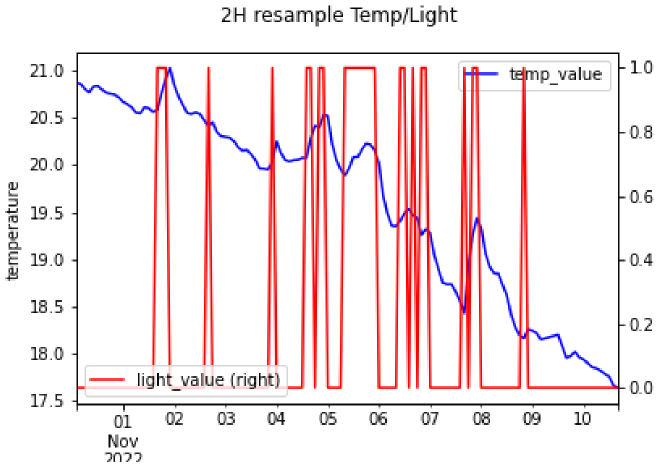
SQLLite - Pandas Integration → Example

- **SQLLite Example**
  - No need for a driver → SQLLite db is a file loaded in memory

- **Home Assistant Examples**
  - Read temperature values for inside and outside
    1. Define **SQL queries** and retrieve data
    2. **Process** data on Pandas side
    3. **Resample** data and **interpolate** holes
    4. **Plotting**



  - Compare temperature and light condition
    1. Light as **a presence indicator**
    2. **Forward fill** data for resampling
    3. **Merging** data
    4. **Correlation** between presence and temperature



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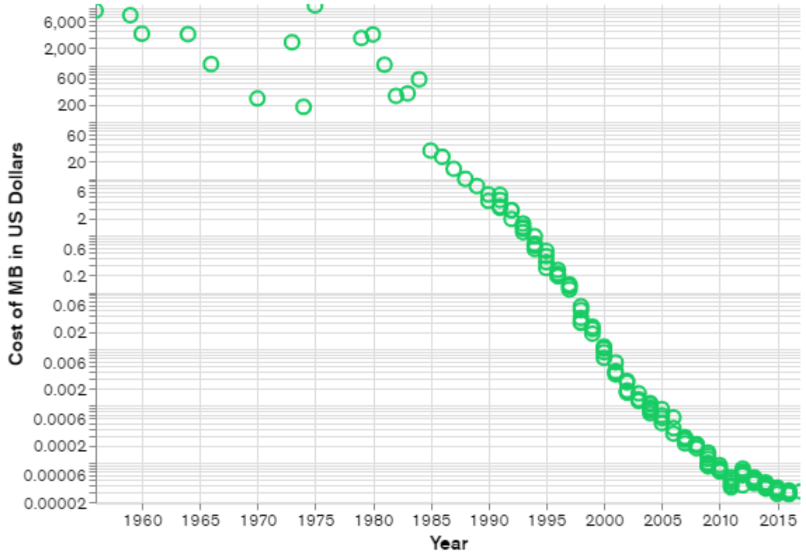
- Pandas integration → Probably shown in parallel with each DB type

NoSQL Databases

- **NoSQL is no relation?**
  - NO! NoSQL only means that relations are memorized using **non-table structures**.
  - Connections are expressed in a different **simple** way → **Single data structure** with **multiple nesting**
- **Why NoSQL?**
  - SQL DBs aim to reduce memory allocation through **schema normalization** and **optimization**
  - Today memory allocation costs are not companies' main problem → **developers effort** is the true cost now, reduce using a simpler DB
  - **Agile-friendly DBs** → Agile methodologies need fast iterations hence fast DBs



- **NoSQL DB types**
  - **Document based:** Data is memorized in the form of **objects** (ex JSON) with keys and values.
    - **Data types:** many datatypes to choose. Also new types can be defined.
    - **Scaling:** Horizontal scaling each time we need to add more data
    - **Examples:** MongoDB is the primary example, but also Dynamo DB, Redis are widely used
  - **Wide-column:** each row couldn't have the same columns.
    - **Usage:** when we **know query types** and we have to save **large amount of data**. IOT usages
    - **Examples:** Cassandra, Hbase
  - **Graphic:** use the concepts of **Nodes** and **Edges**. Nodes save information about persons, places and things while Edges save information about relations between nodes.
    - **Usage:** for social network models, fraud detection and recommendation engines.
    - **Examples:** Neo4j, JanusGraph

MongoDB – the document base king

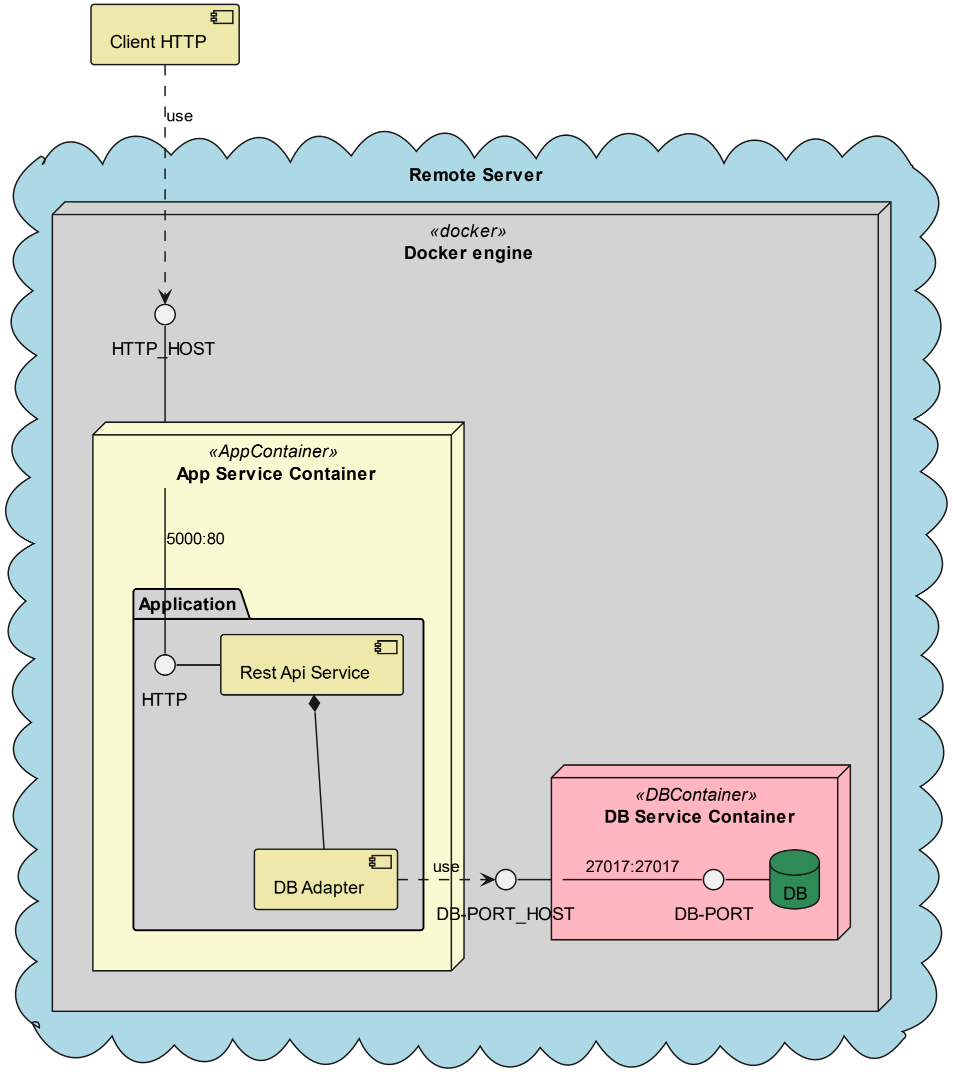
- **NoSQL:** most famous NoSQL database → **Documental DB**
- **Documental form:** Mongo uses **BSON** a dynamic schema version of **JSON.** It's simple JSON for the user
- **History:**
  - **2007 – PAAS:** born as PAAS service component for the company 10gen
  - **2009 – Open Source:** source open and 10gen giving commercial support for the product
  - **2009 - now → MongoDB:** change the name and include other services like *Compass, Atlas, ecc*
- ***Commercial factors:***
  - ***Community version**, Licensed under **SSPL** (Server Side Public License)**: AGPLv3** + **rewrite of section 13*** *"*anyone who offers the functionality of SSPL-licensed software to third-parties as a service must release the entirety of their source code, including all software, APIs, and other software that would be required for a user to run an instance of the service themselves" legit cos companies resold MongoDB as a Service without giving MongoDB nothing. Now they have to release the source code.
    - Like MySQL **cannot be sold** in a production environment
  - **Enterprise version**, licensed under **MongoDB Inc. licenses:** when we want to sell the DB along with our solution.

- **Servers (MongoDB)**:
  - Working on port **27017 TCP**
  - Generally **self-hosted** but is sometimes present in *SAAS, PAAS* environments with preconfigured connectors.
  - Amazon AWS, Azure Database, ecc
  - **Dockerized** nature**:** simplify deployment, scaling, resource allocation, balancing. Even more than SQL solutions
- **Clients (MongoDB Compass):**
  - We use Compass to view database and make fast query.

Rest API Service – MongoDB version → Example

- Multi service dockerization and internal connection
- **App Service Container:**
  - **REST API:** It's a Flask REST API server listening on localhost:80. See Dockerfile entrypoint.
  - **DB adapter:** it's a python module that maps REST method to MongoDB "Queries".
  - **Mapping:** port 80 is mapped to 5000 on the host network because port 80 was already in use
  - **DB connection:** App service connects to the DB service using Docker internal DNS naming resolution. `mongo-service→172.0.0.3`
  - **Restart on failure:** initially a connection error is raised because DB container is not completely initialized.
- **DB Service Container**
  - **MongoDB:** server listening on port 27017. No need for a remapping.
  - **Initialization:** tables initialized from mongo-init.js script. (not needed)
  - **Configuration:** loaded from environment variables.
    - From **dotenv file** if outside docker
    - Passed to **docker-compose env-file** if inside docker

- **Exercise:** Add other REST-API and update DB accordingly → Test with Postman



MongoDB - Pandas integration

Using MongoDB with Pandas is very straightforward

```
import pymongo
import pandas as pd
from pymongo import MongoClient

client = MongoClient()

#point the client at mongo URI
client = MongoClient('Mongo URI')
#select database
db = client['database_name']
#select the collection within the database
collection = db['collection_name']
#convert entire collection to Pandas dataframe
df = pd.DataFrame(list(collection.find()))
```

- Import pymongo
- Start a mongoClient with connection string
- Fetch the database
- Fetch the colllection
- Get the data
- Wrap data into a list and pass to a Dataframe

MongoDB – Dump and Restore a backup → Example

- **Why?**
  - We want to **load an existing dataset dump** to make some experiments.
  - We want to learn how to **backup and restore a mongoDB**
- **Sample collections Link:**
  - Repository that contains a **dump** of Mongo sample collections
  - Loading must occur **after mongo startup!**
  - **2 solutions:**
    - **Manual solution:**
    1. Attach to container instance with a bash terminal: `docker exec –it mongo bash`
    2. Moving into db folder where dump is stored: `cd /data/db`
    3. Call the mongo restore with authentication: `mongorestore -u root -p my_password --nsInclude="SampleCollections.*" --authenticationDatabase admin`
       - -u <user> -p <password> work on the **authentication db** → we need to **tell mongo where are auth infos**
       - --nsInclude="db.collection" → what **db/collections** we want to **backup/restore**
       - /data/db/dump/ → the backup **entry folder**
    - **Automatic solution:**
    1. Define a **mongo-init.sh** script into: `./init/mongo-init.sh /docker-entrypoint-initdb.d/`
    2. Insert the manual steps command inside the script
    3. Mongo will **execute** the script **after DB creation**
    4. **Env** variables are always **accessible** → safe
- **Exercises:**
  1. **Explore DB data** → With MongoDBCompass db explorer
  2. **Show pokemon images** → With pandas
  3. **Experiment on other collections** → Fetch data, insert data, integrate in pandas

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Time Series – A machine learning prespective

- **Pattern:** some type of **data** (simple or complex) that we want to **classify.**
  - Hand-writing, movement, photo, fingerprint, vibration frequency, ecc → can be **classified** in a **predetermined SET** of abstract boxes, containers, logics aka **classes.** Ex if classes cat=1, dog=2 a photo with a cat is classified with 1
  - **Static vs Dynamic → Static =** time independent (photo, fingerprint) **Dynamic =** time dependent (movement, hand-writing)
  - **Unique** in some **Features** → pixels in photos, 3D position in movement, minutiae in fingerprint. **So, a List/Vector of Features**
  - **Classification** = **f: pattern->class** hence a pattern must be converted to a numeric representation, a numerical vector of features called **Feature Vector.** Static: **f: (Int, …) -> Int** Dynamic: **f: [(Int, …) …] -> Int**
- **Time series pattern:** a Dynamic pattern composed by **multiple features vectors** in the number of time series length.
  - To classify a hand gesture, track the position of the hand during a time window (ex 1 sec=30 FPS) and record the features vector at each frame. A feature vector is **v = [x, y, z]**, for 30 FPS it's a vector of [x, y, z] of length = 30. **[v1, v2, …, v30]**
- **Standard DB and Time Series**
  - A SQL DB fails to store all the data because it's relational and it need to store a new row for every time-frame. Can be optimized
  - A NoSQL DB is sometimes used to store time series data in a big data environment
  - In a **telemetry driven environment** must optimized according to data type, time series nature. Compression of data, optimize
  - Need a support for **time series operations** and query. Different from a normal DB query. Ex interpolate, resample, aggregate
  - **Integration** to commonly used big-data **time-series framework** and tools. Ex Pandas

Influx DB – Intro 1

_time	_measurement	location	scientist	_field	_value
2019-08-18T00:00:00Z	census	klamath	anderson	bees	23
2019-08-18T00:00:00Z	census	portland	mullen	ants	30
2019-08-18T00:06:00Z	census	klamath	anderson	bees	28
2019-08-18T00:06:00Z	census	portland	mullen	ants	32

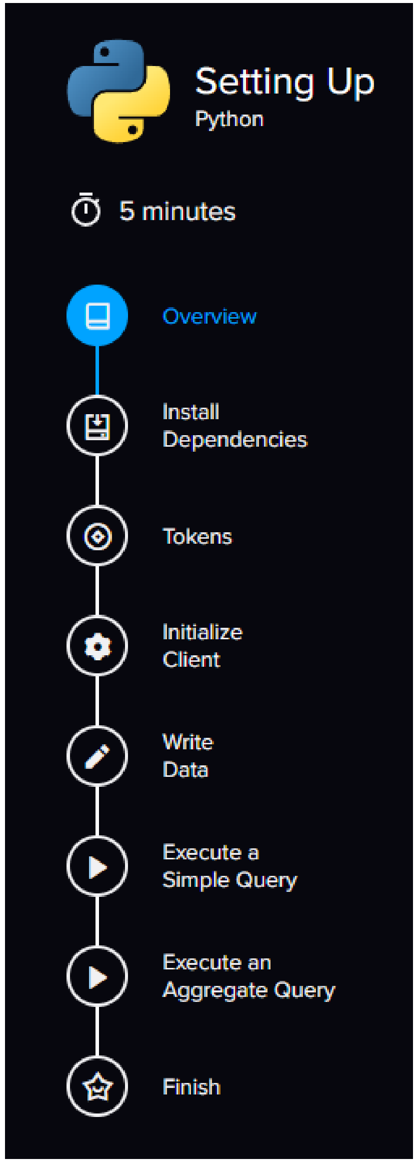
- **Why**
  - Support for **time series operations** and **query**
  - A **high-performance** time series **engine**
  - A **powerful API & toolset** for real-time applications
  - A **massive community** of open-source developers
  - **Static schema → most performance** in data retrieve
- **Data Element**: list of data elements with correspondent column in table
  - **Timestamp[_time]:** it stores timestamp in a nanosecond form according to **RFC3339 UTC**
  - **Measurement[_measurement]:** a string tag for measurement. Container for tags, fields and timestamps
  - **Fields[_field, _value]:** field key _field and a field value _value. Key=[string], Value=[string, float, int or boolean]. NOT INDEXED
  - **Field set:** collection of fields(key, value) pairs associated to same timestamp
  - **Tags:** customizable column. Key=name of column, value=the value of the row in that column. INDEXED
  - **Tag set:** like Field set
  - **Bucket:** All InfluxDB data is stored in a bucket. A **bucket** combines the concept of a **database** and a **retention period** . Explicit **bucket schema** is required for each measurement.
  - **Series:** A **series key** is a **collection of points** that share a **measurement**, **tag set**, and **field key**. A series includes **timestamps** and **field values** for a given **series key**.
  - **Point:** A **point** includes the **series key**, a **field value**, and a **timestamp**
  - **Organization:** An InfluxDB **organization** is a **workspace** for a **group of users**. <u>All dashboards, tasks, buckets, and users belong to an organization</u>.

Influx DB – Intro 2

- **Internal Structure:** data elements are stored in **time-structured merge tree (TSM)** and **time series index (TSI)** files to efficiently compact stored data.
- **Data Schema:** InfluxDB also provides a **tabular data schema** (used to raw view and CSV export) that includes the following:
  - **Annotation rows:** Describe column properties
  - **Header row:** Defines column labels that describe data in each column: (table, _time, _value, _field, _measurement, …)
  - **Data Row:** Each data row contains the data specified in the header row for one point.
  - **Other columns:** Optional columns: annotation, result, table
  - **Group keys:** grouping records that share common values in specified columns
- **Design Principles:** InfluxDB implements optimal design principles for time series data.
  - **Time ordered data:** improve performance
  - **Strict update and delete permissions:** InfluxDB tightly restricts **update** and **delete** permissions. Deletes generally only affect data that isn't being written to.
  - **Read and Write queries first:** InfluxDB prioritizes read and write requests over strong consistency. If frequency is high a read could not return most recent data.
  - **Schemaless design:** InfluxDB uses a schemaless design to better manage discontinuous data. Ex start-report-stop devices
  - **Datasets over individual points:** points are differentiated by timestamp and series, no IDS → aggregate is a common operation
  - **Conflict resolution**: If a new field value is submitted for a point, InfluxDB updates the point with the most recent field value.

Influx DB – Explore the basics→ Example

- **Setting up with python:**
  - **Examine docker-compose:** Spin the instance
  - **Connect to localhost:8086:** Examine the GUI
  - **Python integration:** Influx DB include how to connect to influx directly inside the instance so, we only must copy API tokens edit server and follow the tutorial.
  - **Select a bucket:** we must have a container for our data
  - **Write to the bucket:** write data to the bucket using examples in tutorial
  - **Try in GUI:** visualize your data in GUI
- **Loading my Home Assistant dump:**
  - **Spin a clean instance:** delete volumes
  - **Attach to container bash:** `docker exec -it influxdb_container bash`
    we can find in container the backup/ folder
  - **Restore the dump:** `influx restore <folder>`
  - **How could we automate the backup??**
  - **Find new buckets:** homeassistant and homeassistant-aggregated are created and they are on a different organization, switch organization and find them.
  - **Examine buckets:** examine the two buckets, find differences, explain what they do
  - **Make some visual queries on GUI:** make some queries and understand query textual form
  - **Look at textual queries generated by visual queries** -> Helps a lot understanding queries
  - **Then we will see textual queries**



Influx DB - Queries

```
from(bucket: "example-bucket")
    |> range(start: -1h)
    |> filter(fn: (r) => r._measurement == "example-measurement" and r.tag == "example-tag")
    |> filter(fn: (r) => r._field == "example-field")
```

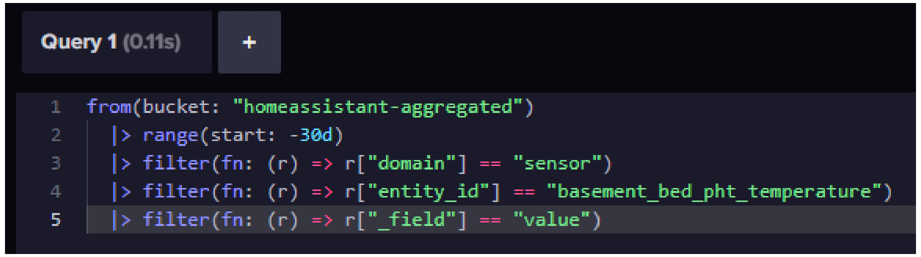
- **Flux:** is the language used by Influx DB. It' functional, stream-like → a flux
- **Data flow up-down:** from source to simple element
- **From:** define the source bucket
- **Range:** define the time range. Start and Stop of type date. Also: 1s, 1m, 1d, 1we, 1mo, 1y, ecc
- **Group:** we have group-by `|> group(columns: ["host"], mode: "by")`
- **Sort:** not so used `|> sort(columns: ["host", "_value"])`
- **Limit:** limit the output data `|> limit(n: 4)`
- **Aggregate:** automatic aggregate on window size with operation `|> aggregateWindow(every: 20m, fn: mean)`
- **Map:** `|> map(fn: (r) => ({ r with _value: r._value * r._value }))   "by")`
- **Moving average:** compute the moving average over n samples `|> movingAverage(n: 5)`
- **Timed moving average:** over time `|> timedMovingAverage(every: 2m, period: 4m)`
- **Derivative:** for rate change `|> derivative(unit: 1m, nonNegative: true)`
- **Histogram:** compute the histogram with upper bound over some defined bins
- **Fill:** forward fill or static fill of null `|> fill(usePrevious: true)` `|> fill(value: 0.0)`
- **Median/quantile:** median and percentile `|> median()` `|> quantile(q: 0.99, method: "estimate_tdigest")`
- **Cumulative sum:** `|> cumulativeSum()`

```
|> histogram(
    column: "_value",
    upperBoundColumn: "le",
    countColumn: "_value",
    bins: [100.0, 200.0, 300.0, 400.0],
)
```

Pandas Influx DB – Integration → Example

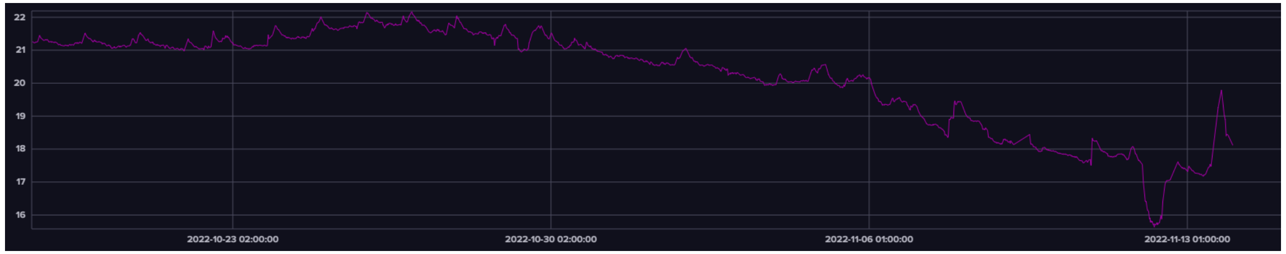
- **Influx supports pandas from scratch:** query_data_frame() function
- **Use homeassistant-aggregated bucket!!! → homeassistant bucket has a huge amount of data it will destroy your CPU** "uomo avvertito…"

1. **Try queries on home assistant aggregated**



Query 1 (0.11s) +

```
from(bucket: "homeassistant-aggregated")
  |> range(start: -30d)
  |> filter(fn: (r) => r["domain"] == "sensor")
  |> filter(fn: (r) => r["entity_id"] == "basement_bed_pht_temperature")
  |> filter(fn: (r) => r["_field"] == "value")
```



2. **Visualize graphs or Raw data each time:**
   - Try with different graphs types, customize duration
3. **Export a query on CSV**

   - Analyze the csv
4. **Exercises:** some exercises hard and easy with influx DB queries.
   - Influx has many functions probably all functions you will ever need

END

- Good luck for the course