Ducks to the rescue

ETL using Python and DuckDB

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Speaker Introduction

Marc-André Lemburg

- Studied Mathematics, Computer Science and Physics
- CEO eGenix.com GmbH
- Senior Solution Architect, Consulting CTO and Coach
- EuroPython Society Fellow and former Chair
- Python Software Foundation Fellow and former director
- Python Core Developer (Unicode, DB-API, platform module, ...)
- Co-founder Python Meeting Düsseldorf
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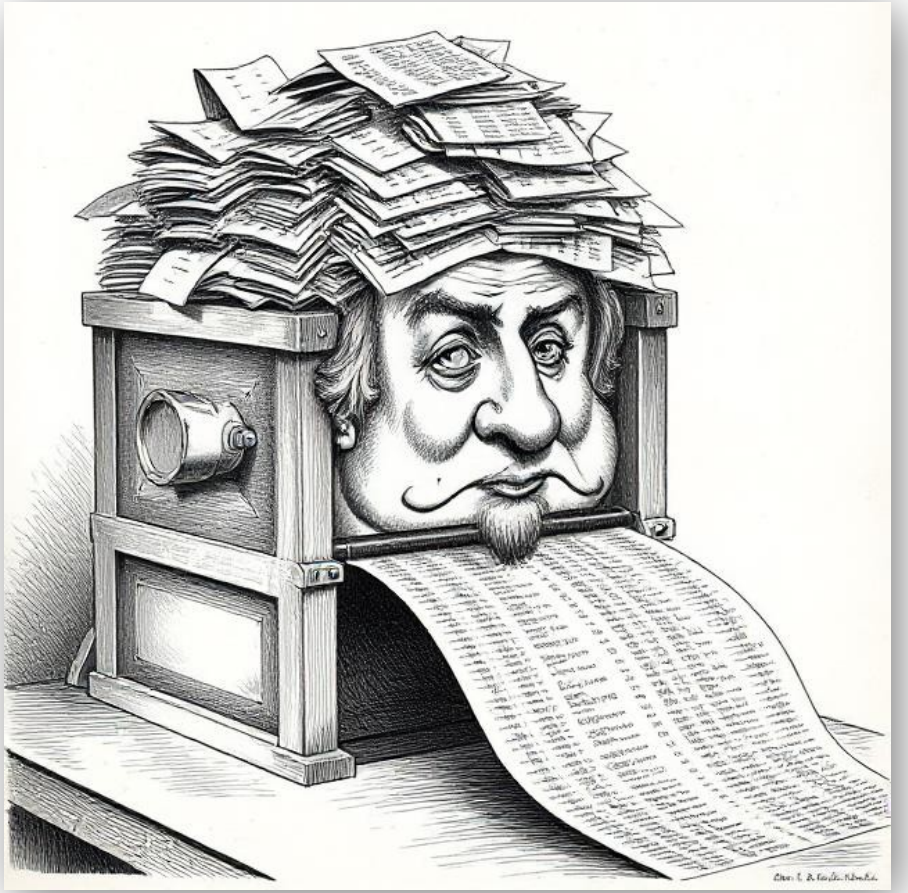
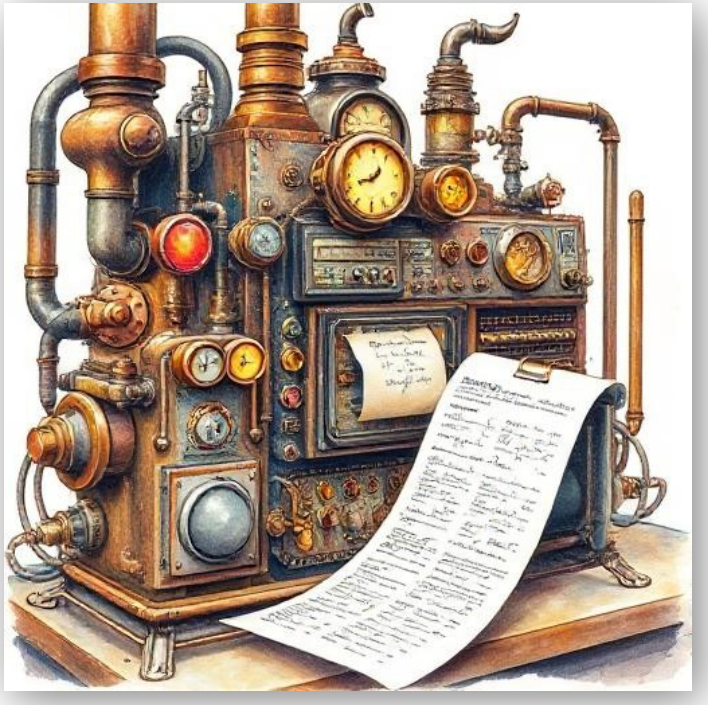
Motivation



ETL – Extract, Transform, Load

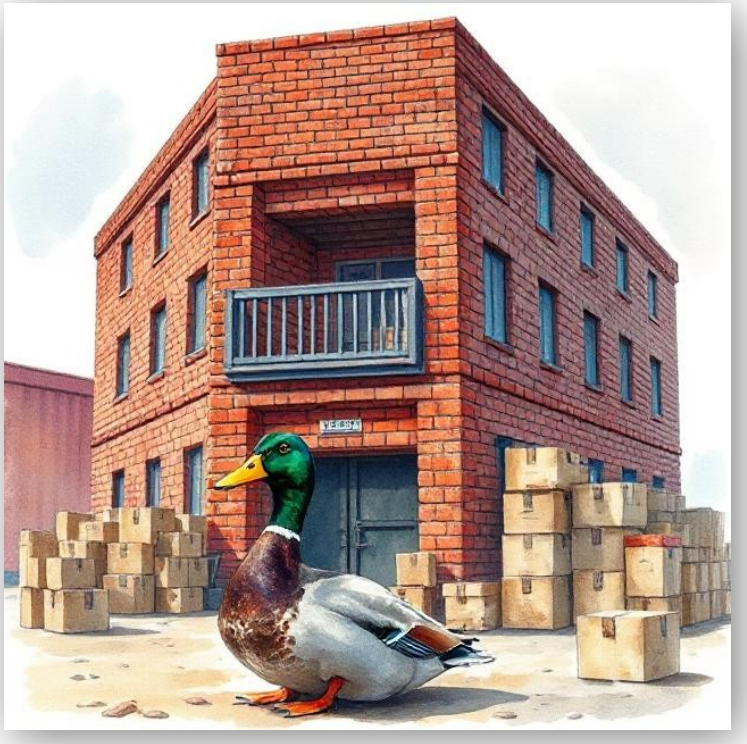
- Move data from a source to a target, transforming it along the way
  - In business, a synonym for "data conversion"

- Extract
  - Pull data from a data source and make it available to the ETL process
- Transform
  - Take the data and adapt it for loading
- Load
  - Load the data into the target database
- Process
  - Send the data off for processing



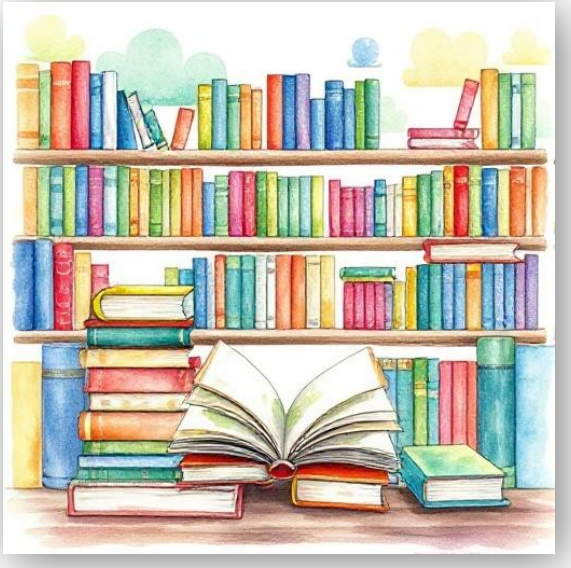
What's DuckDB ?

- Open source, in-process analytics data storage (OLAP)
- Column based (Apache Arrow)
- Persistent and in-memory
- SQL as standard query language
- Single writer / multiple readers
- *Similar to SQLite, but for OLAP workloads*
- Great Python support



Typical ETL steps

- Read the data
  - Download data from FTP, an object store, or the web
  - Fetch an RSS feed and read the listed web resources
  - Read a CSV or Excel file
  - Read tables from a webpage or PDF
  - Talk to a database and query data or run reports
  - Get data from an email box
  - Listen on a stream input for data, e.g. MQTT, Kafka queues, etc.
- Save data locally or in an object store



Typical ETL steps

- Massage the data for easier loading
  - Adjust encoding (to UTF-8)
  - Remove whitespace
  - Remove extra reporting lines
  - Trim down the data to what you are really interested in
  - Extract meta data
  - Reformat input data into CSV or Parquet files

- Should be done using a streaming approach to reduce memory load
  - A line based approach is typically good enough
  - Polars streaming can help with this

Typical ETL steps (using DuckDB)

- Load data into DuckDB
  - Use very fast DuckDB tooling for this
    - SELECT * FROM read_csv(…)
  - Avoid reading data into Python first
    - takes much longer
    - uses more memory
- Load data into staging tables
  - or even a separate database

Typical ETL steps (using DuckDB)

- Transform data in DuckDB
  - Filter out unneeded and duplicate data
  - Validate data
  - Fill in missing data (NULLs and N/A values)
  - Correct data/time formatting
  - Adjust int/float data to fit the target database
  - Convert data types where needed
  - Rename columns to match target database

- Use DuckDB SQL for this
  - DuckDB uses the PostgreSQL dialect, with extensions
  - Hint: LLMs are great at writing SQL for you

Typical ETL steps (using DuckDB)

- Merge data into target database
  - Use DuckDB SQL for preparing / processing the merge
  - Fall back to Python if SQL gives you problems
    - Polars can help with this, since it is integrated with DuckDB
  - Use native Duck integrations for writing to targets
    - PostgresSQL
    - MySQL
    - SQLite
    - Iceberg and Delta Lakes

    or stream via Python using the DB API
- Remove or clear the staging tables again
  - or move the data to archive tables

Advanced ETL

Guidelines

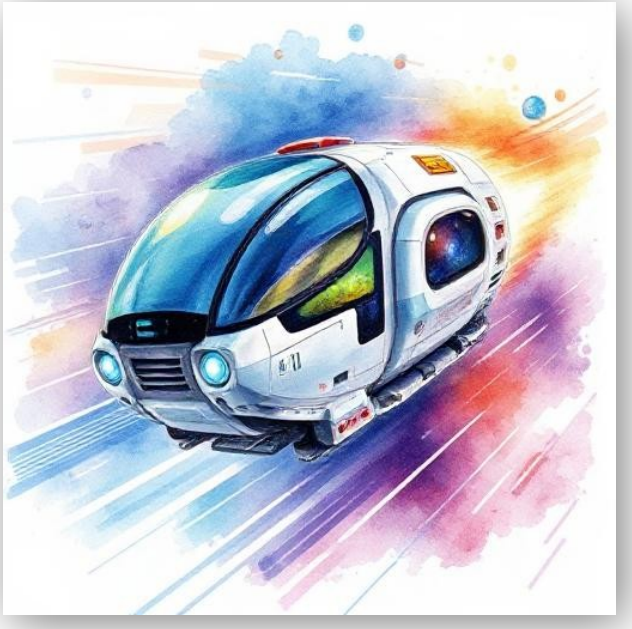
- **Know your queries**:
  You should have good knowledge of how the target data is going to be used

- **Use the Pareto principle (80/20 rule)**:
  Optimize for often used queries

- **Keep a healthy balance**:
  Performance and space requirements are often trade-offs

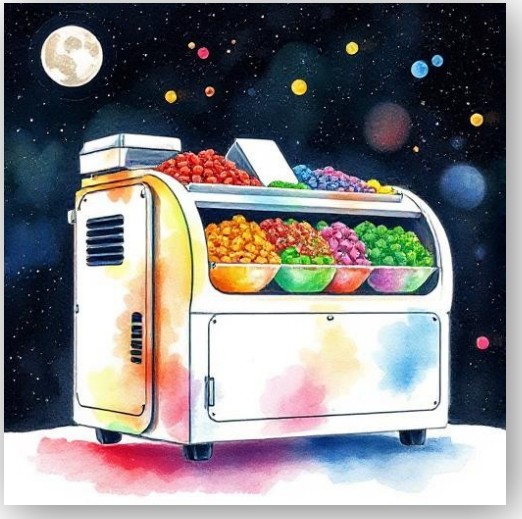
Advanced ETL

- Optimize the data for querying in your target database
  - Goal: avoid query time joins
  - Move joins to insert time
    - Denormalize your data
    - It's ok to keep multiple copies around
    - Just make sure data is updated as part of the ETL process
  - Use materialized views
    - Update materialized views at low query times
    - (DuckDB does not support these at the moment)



Advanced ETL

- Add / update indexes carefully
  - Only add them based on query statistics
  - Index updates should be deferred to after the loading has finished
- Partition the data
  - This is only needed for really large datasets
  - Can be done based on index columns
- Deduplicate data
  - Sometimes needed to remove duplicate records
  - Often needed when dealing with streamed data, e.g. IoT data, sensor data, mobile data, etc.



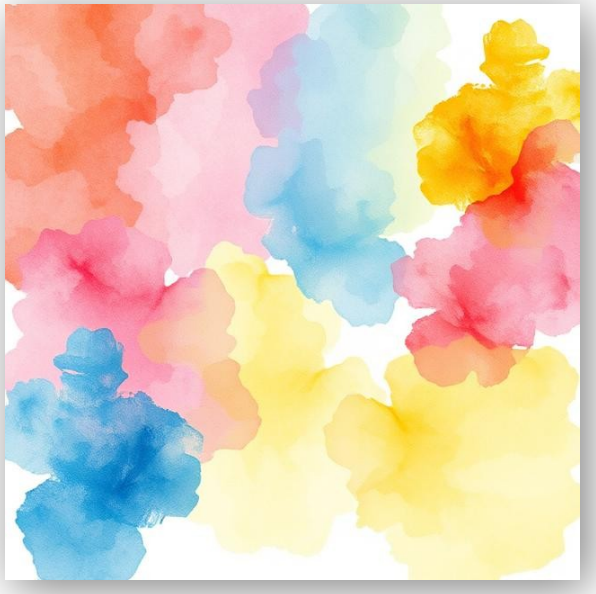
Advanced ETL

- Prefilter data
  - Your queries may not need all the data
  - Leave the full set in DuckDB
- Preaggregate data
  - Often enough you only need aggregates over certain windows
  - Leave the full set in DuckDB
- Precaluate data sketches
  - Data sketches produce results which are only accurate to a certain percentage
  - They run a lot faster than full queries

Conclusion

- DuckDB makes ETL a whole lot easier
  - Most ETL steps can be handled in a single process
  - No need for complex workflow setups using e.g. Airflow
  - Fast
  - Easy to debug
  - Work directly on the data

- Just a “uv add duckdb” away...



Main takeaway: Never stop learning and trying out new things

Thank you for your attention !

Time for discussion

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References

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