Efficient AI with Rust Lab
Rapid Time Series Datasets Library
RWTH Aachen University

Group 1

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RWTH AACHEN UNIVERSITY

Overview

Goal

- Preprocessing of time series datasets

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- Python package implemented in Rust

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- Passing data by reference

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- Two types of datasets

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Data Input Format

Input 3D numpy array:

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Row	Features
1	...
2	...
3	...
4	...
. . .	
n-1	...
n	...

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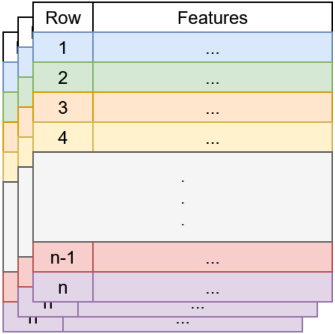

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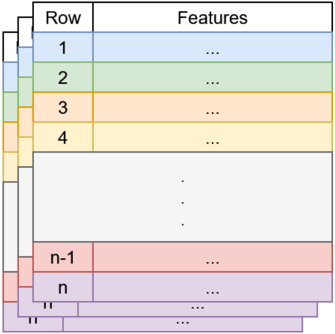
In practice

- Forecasting datasets:
  - One instance



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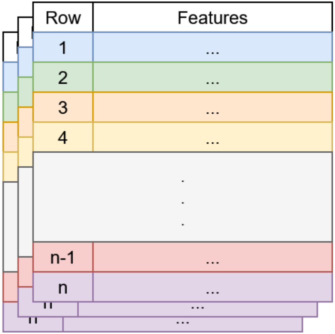
In practice

- Forecasting datasets:
  - One instance
- Classification datasets:
  - Multiple instances



Splitting I

Goal: Split a time series dataset into three parts: training, validation, and test.

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Splitting II (Random Split - Classification Data)

How it works:

1. Validate the proportions of train, validation, and test sets.

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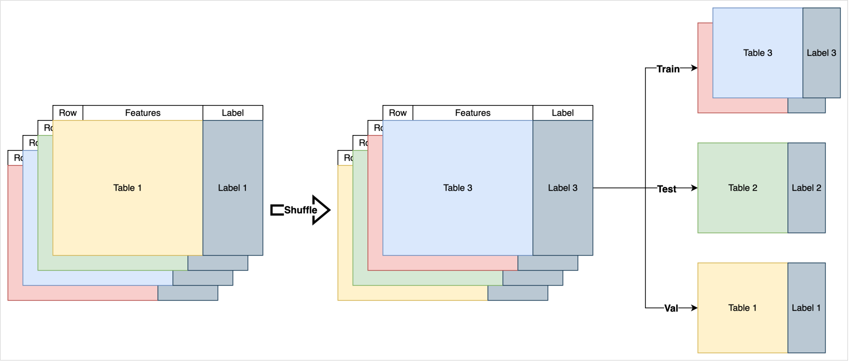
4. Split the instances into three sets.
5. Return the three sets as separate datasets.

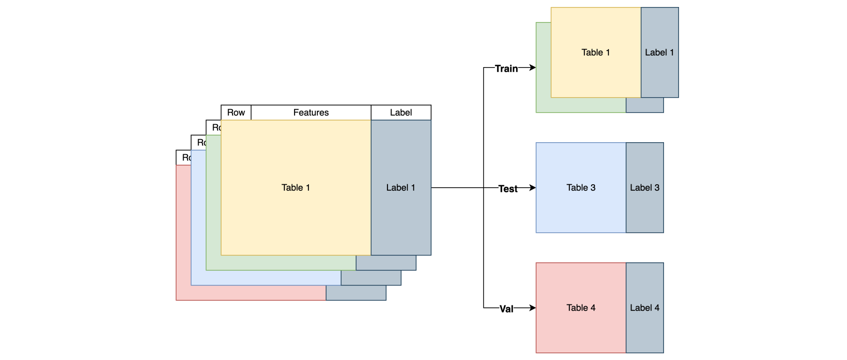
Splitting III (Random Split - Classification Data)



Random split example

Splitting IV (In-Order Split - Classification Data)

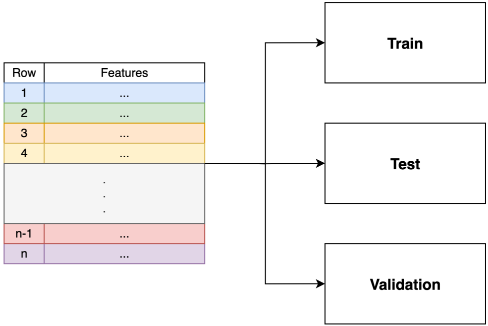
Works very similar to the random split, but it **doesn't shuffle** the dataset anymore.



In-Order split example

Splitting V (Temporal Split - Forecasting Data)

Similar to the in-order split, but this time we are dealing with forecasting data, which in most cases is only one instance and we split over **timesteps** and not instances anymore.



Temporal split example

Performance considerations

Copying

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When to copy?

- For `ForecastingDataSet`:
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- For `ClassificationDataSet`:

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- For `ClassificationDataSet`:
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Data-flow

Forecasting Dataset Data-Flow

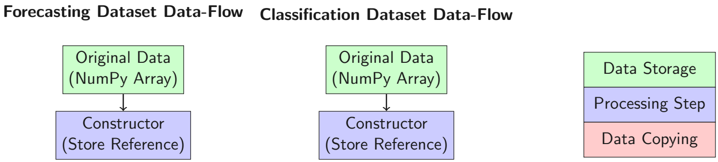
Original Data
(NumPy Array)

Classification Dataset Data-Flow

Original Data
(NumPy Array)

Data Storage
Processing Step
Data Copying

Data-flow


Forecasting Dataset Data-Flow
Original Data (NumPy Array)
Constructor (Store Reference)
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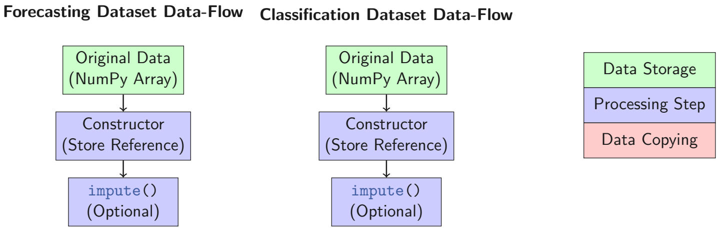
Forecasting Dataset Data-Flow
Original Data (NumPy Array)
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impute() (Optional)
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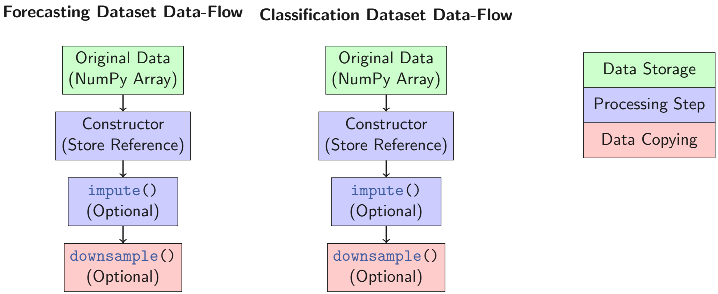
Forecasting Dataset Data-Flow
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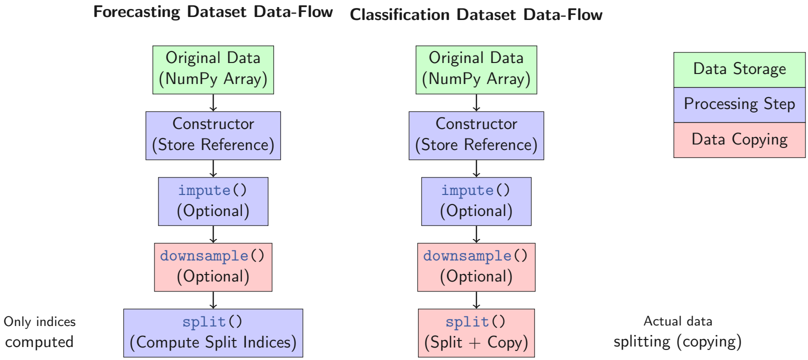
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Original Data (NumPy Array)
Constructor (Store Reference)
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split() (Compute Split Indices)
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Original Data (NumPy Array)
Constructor (Store Reference)
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split() (Split + Copy)
Actual data splitting (copying)
Data Storage
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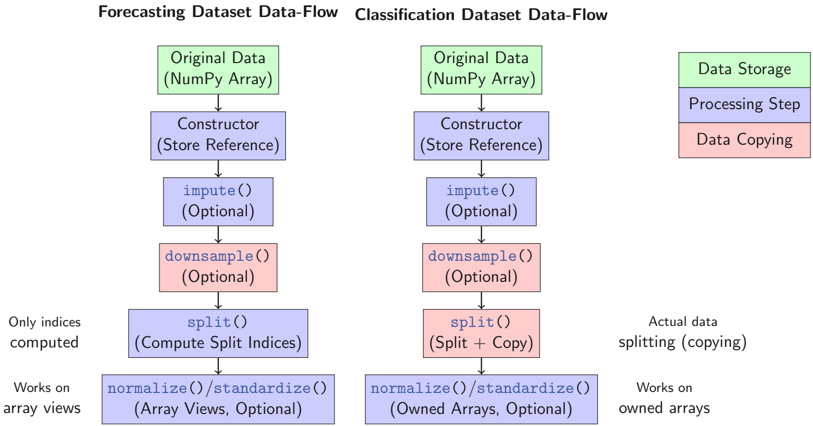
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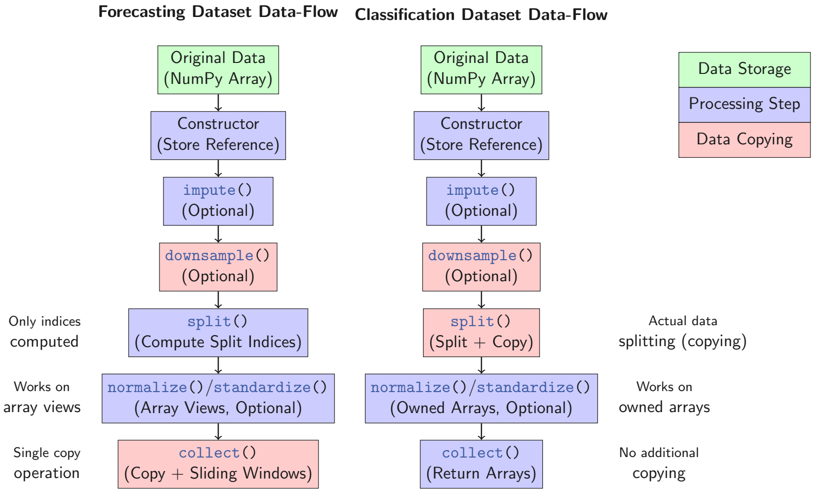
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collect() (Copy + Sliding Windows)
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Single copy operation
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No additional copying
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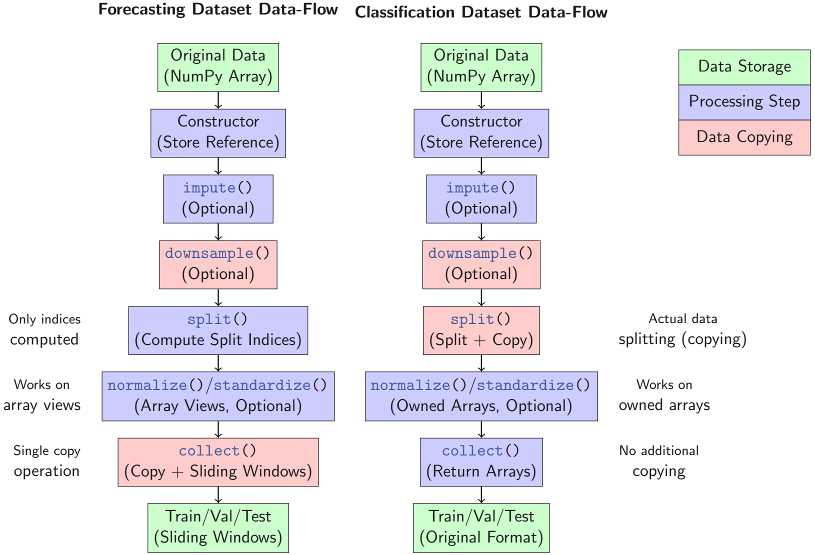
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Pipeline Design

ForecastingDataSet

```
# Create instance
fore = ForecastingDataSet(
  data, 0.7, 0.2, 0.1
)

# call the pipeline methods
fore.impute(
  ImputeStrategy.Median
)
fore.downsample(2)
fore.split()


fore.normalize()
fore.standardize()

# collect the results
fore_res = fore.collect(3, 1, 1)
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```

ClassificationDataSet

```
# create instance
clas = ClassificationDataSet(
  data, labels, 0.7, 0.2, 0.1
)

# call the pipeline methods
clas.impute(
  ImputeStrategy.Median
)
clas.downsample(2)
clas.split(
  SplittingStrategy.Random
)
clas.normalize()
clas.standardize()

# collect the results
clas_res = clas.collect()
```

Downsampling I

Goal: Reduce the number of data points in a time series dataset.

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Example:

- Downsampling factor of 2: Every second data point is kept

Downsampling II

f1	f2	f3
1	2	1
3	4	6
5	6	11
7	8	16
9	10	21
11	12	26

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Downsampling example with a factor of 2

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How it works:

- The downsampling function takes a time series dataset and a downsampling factor as input.

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- Downsampling does not yield a continuos data structure.

Standardization

Goal: Transform each feature in a time series dataset to have a **mean** of **0** and a **standard deviation** of **1**.

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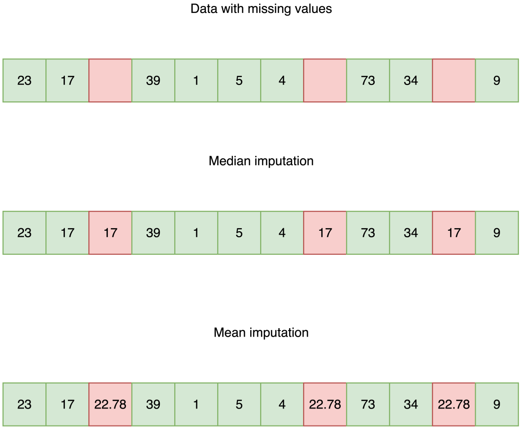

Median and Mean imputation methods applied to an array

Imputing III

Forward-Fill and Backward-Fill imputation methods applied to an array

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- Use the PyO3 testing framework to run the tests.

Unit Tests II

Example: Testing the `impute()` method.

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- Create a simpe numpy array with missing values.

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- Create a simpe numpy array with missing values.
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- Check if the missing values are filled correctly.

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- The coverage is not as detailed as with the standard Rust testing framework, but it is sufficient for our needs.

Unit Tests III

How we calculated the coverage:

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Results:

- Number of all methods: 47
- Number of methods called during tests: 40
- Coverage: 85.1%

Benchmarking

Goal:

- Compare vs. PyTorch TimeSeriesDataSet

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- Additionally: Numpy and Python

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How:

- Implmenent similar Module
- Vary parameters
- Test on real data
- Measure timings and memory use

Measurements

Timing:

- Measure timing for each method

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Peak Memory:

- Track memory use via Python
- Record peak use
- **But:** Measurements show the same value (312 MB)
- Setup or measurement error.

Total setup durations I

- **Goal:** Measure total setup over different paremeters

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- **Here:** Fixed stride, normalization, downsampling, imputing and splitting

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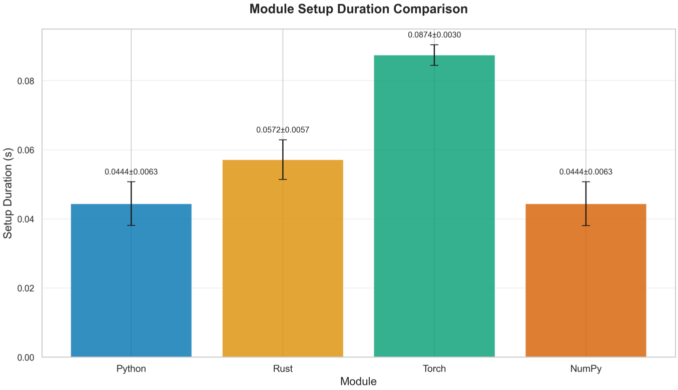

Setup durations on GunPoint

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Explanation:

- Numpy uses vectorized operations in C

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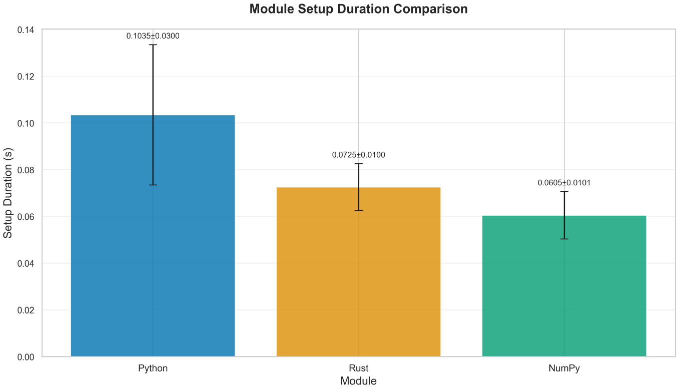
- Torch overhead from Pandas

Total setup durations II

- **Goal:** Measure total setup over different paremeters



Setup durations on GunPoint

Total setup durations II

- **Goal:** Measure total setup over different paremeters

Explanation:

- More processing benefits Rust and Numpy

Total iteration durations

- **Goal:** Measure total data retrieval

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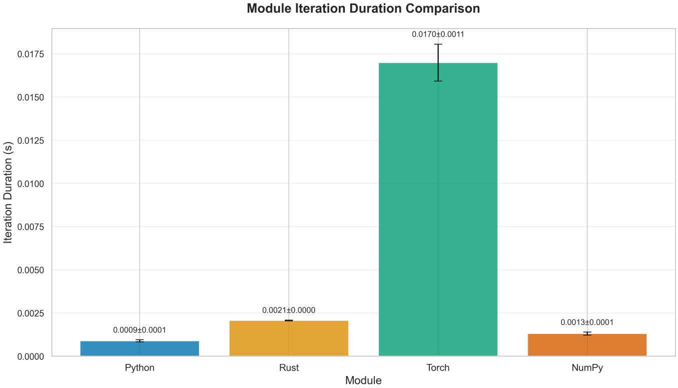

Iteration durations on GunPoint

Total iteration durations

- **Goal:** Measure total data retrieval
- **Motivation:** Pytorch uses lazy compute

Explanation:

- PyTorch slowest due to deferred preprocessing during retrieval

Imputing durations

- **Goal:** Measure imputing in isolation

Imputing durations

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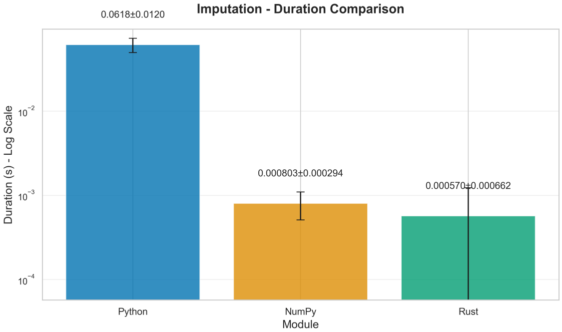

Imputing durations on GunPoint

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Explanation:

- Rust benefits from compiler
- NumPy benefits from partial vectorization

Normalization durations

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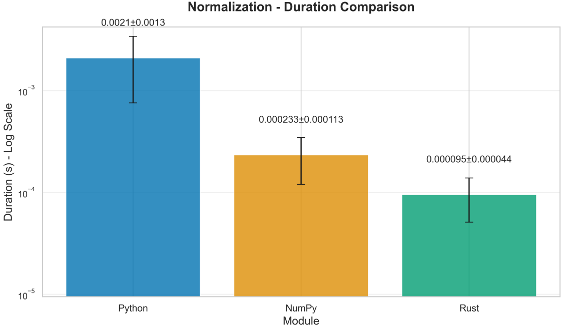

Normalization durations on GunPoint

Normalization durations

- **Goal:** Measure normalization in isolation

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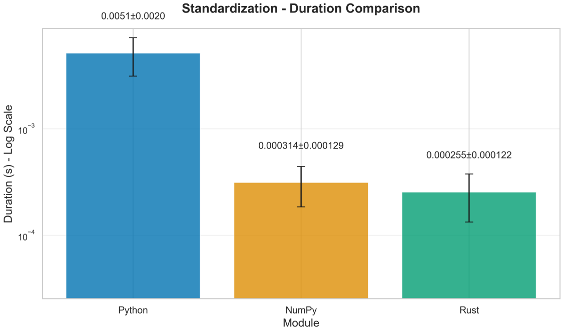

Standardization durations on GunPoint

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Downsampling durations

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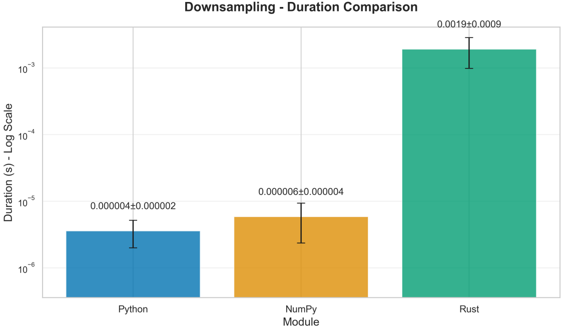

Downsampling durations on GunPoint

Downsampling durations

- **Goal:** Measure downsampling in isolation

Explanation:

- Rust slowest due to costly data copying

Data collection durations

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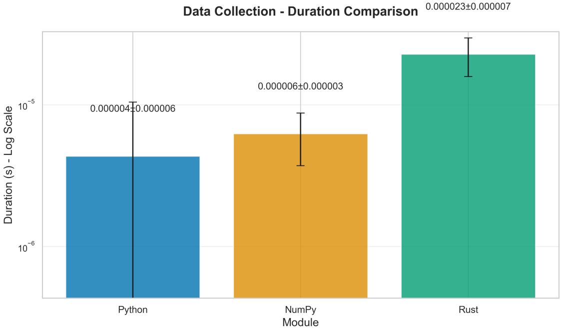
Data collection durations

- **Goal:** Measure data collection in isolation



Data collection durations on GunPoint

Data collection durations

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Explanation:

- Rust slowest due to Python data transfer

Future Work

- Add more preprocessing methods

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- Improve documentation and examples

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- Add more preprocessing methods
- Improve documentation and examples
- Optimize memory usage further at parts where possible
  - E.g., avoid unnecessary copies
  - Use more efficient data structures

Thank you for your attention!

Questions?