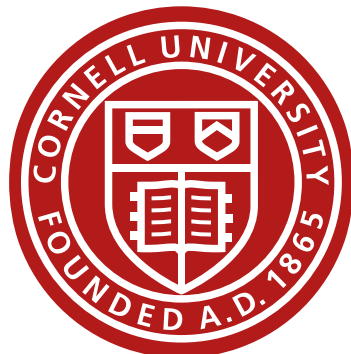# N²: A Unified Python Package and Test Bench for Nearest Neighbor-Based Matrix Completion

Caleb Chin, Aashish Khubchandani, Harshvardhan Maskara, Kyuseong Choi, Jacob Feitelberg, Albert Gong, Manit Paul, Tathagata Sadhukhan, Anish Agarwal, Raaz Dwivedi

Motivation

Nearest neighbor (NN) methods are effective tools for matrix completion applications but:

- There's no unified and extendable framework to consolidate NN methods for rapid experimentation and development.
- There's no standardized real-world benchmarks for matrix completion methods across multiple real-world datasets.

Solution

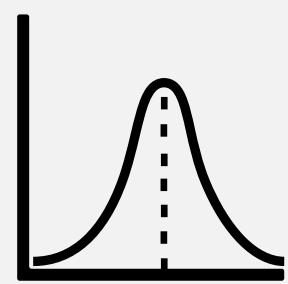N² is a **unified Python package** and **testbed** designed to:

- Consolidate a broad class of NN-based methods through a **modular, extensible interface**.
- Stress-test matrix completion methods on **diverse real-world datasets** from healthcare and recommendation systems to causal inference and LLM evaluation.
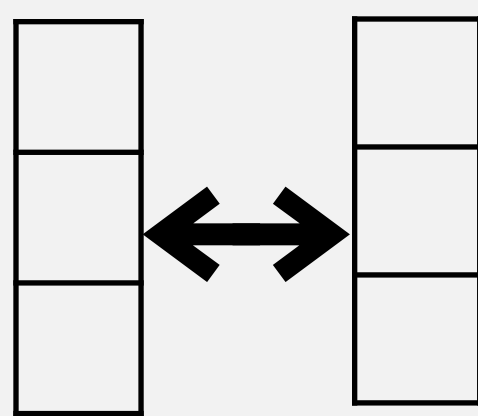
N² Framework
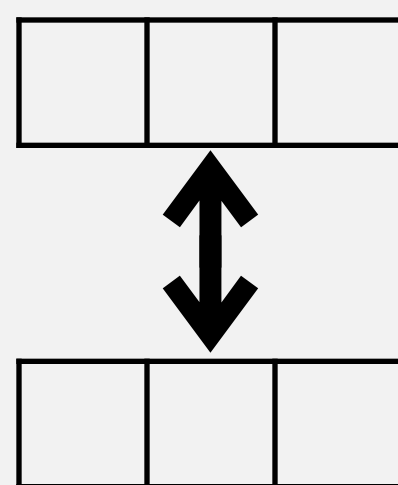
DataType

Entry type:
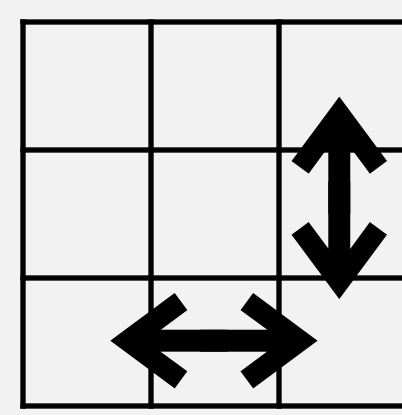
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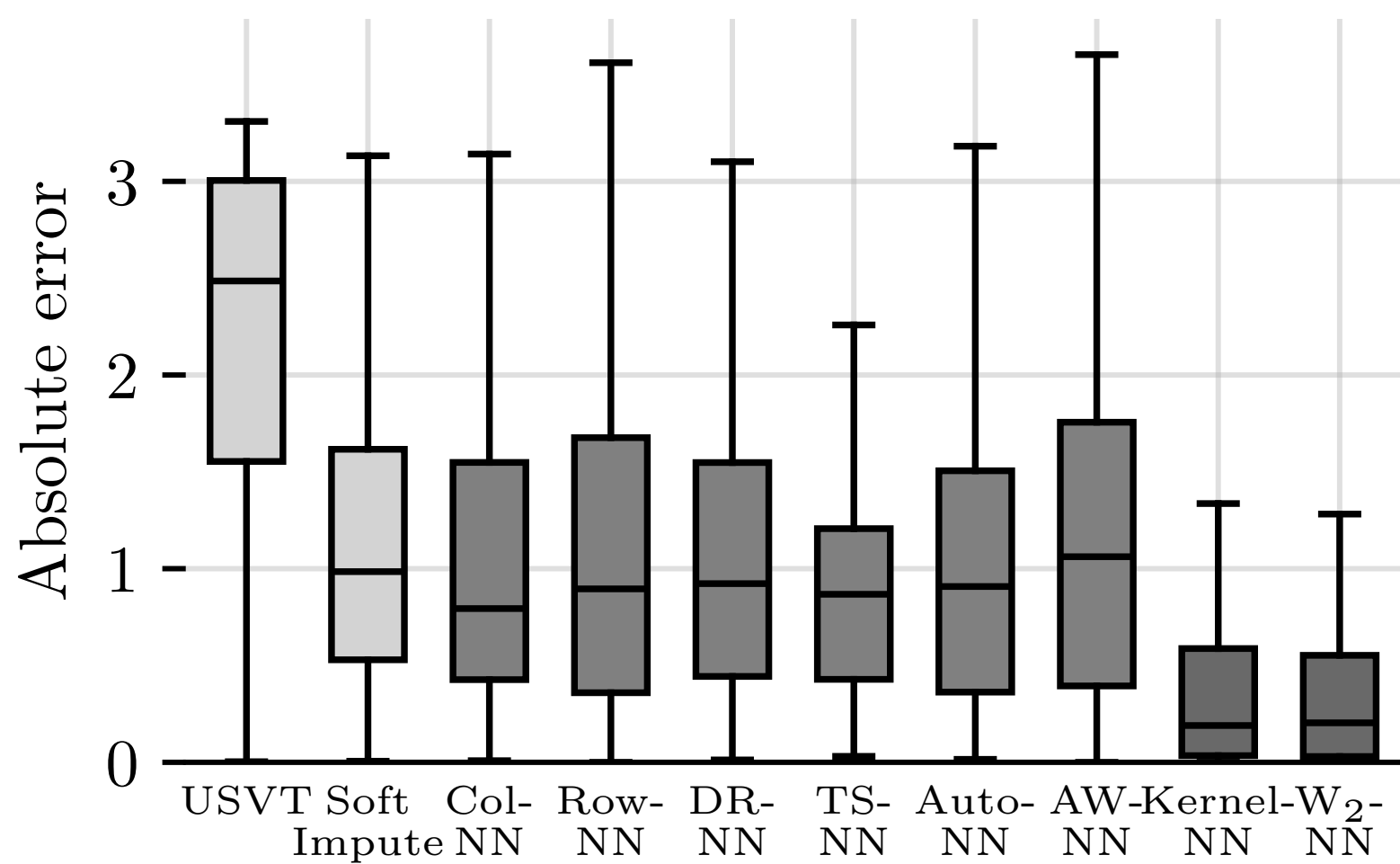
Define:
- DISTANCE
- AVERAGE

EstimationMethod

ColNN

RowNN

DRNN, TSNN, …

N²-Bench

Personalized Healthcare: Heartsteps Study

Recommendation Systems: MovieLens

Counterfactual Inference: California Prop. 99

Takeaways

- Across-the-board reductions in error.
- Our findings lead us to introduce AutoNN, which automatically adjusts to the underlying noise level and debiases automatically.
- The modularity of the package and testbed allows for easy prototyping and benchmarking of new NN approaches.

Paper

GitHub

N²: A Unified Python Package and Test Bench for Nearest Neighbor-Based Matrix Completion
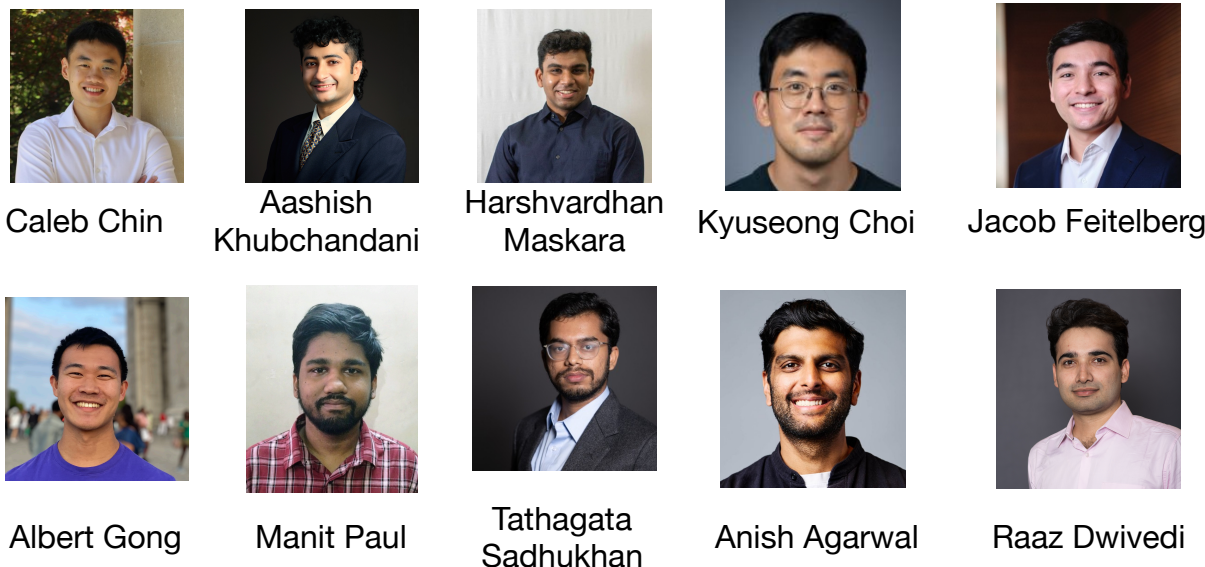
Caleb Chin · Aashish Khubchandani · Harshvardhan Maskara · Kyuseong Choi · Jacob Feitelberg
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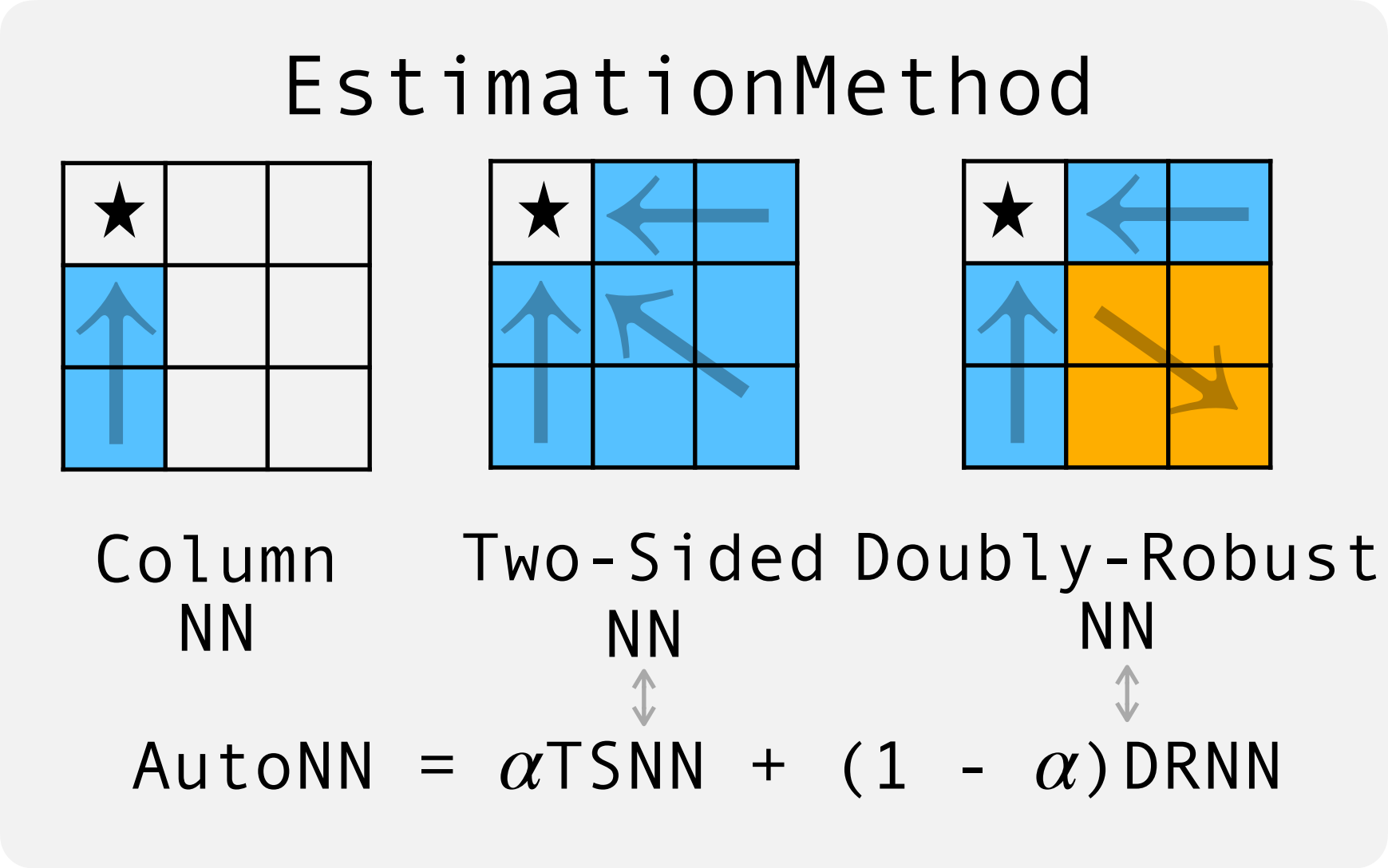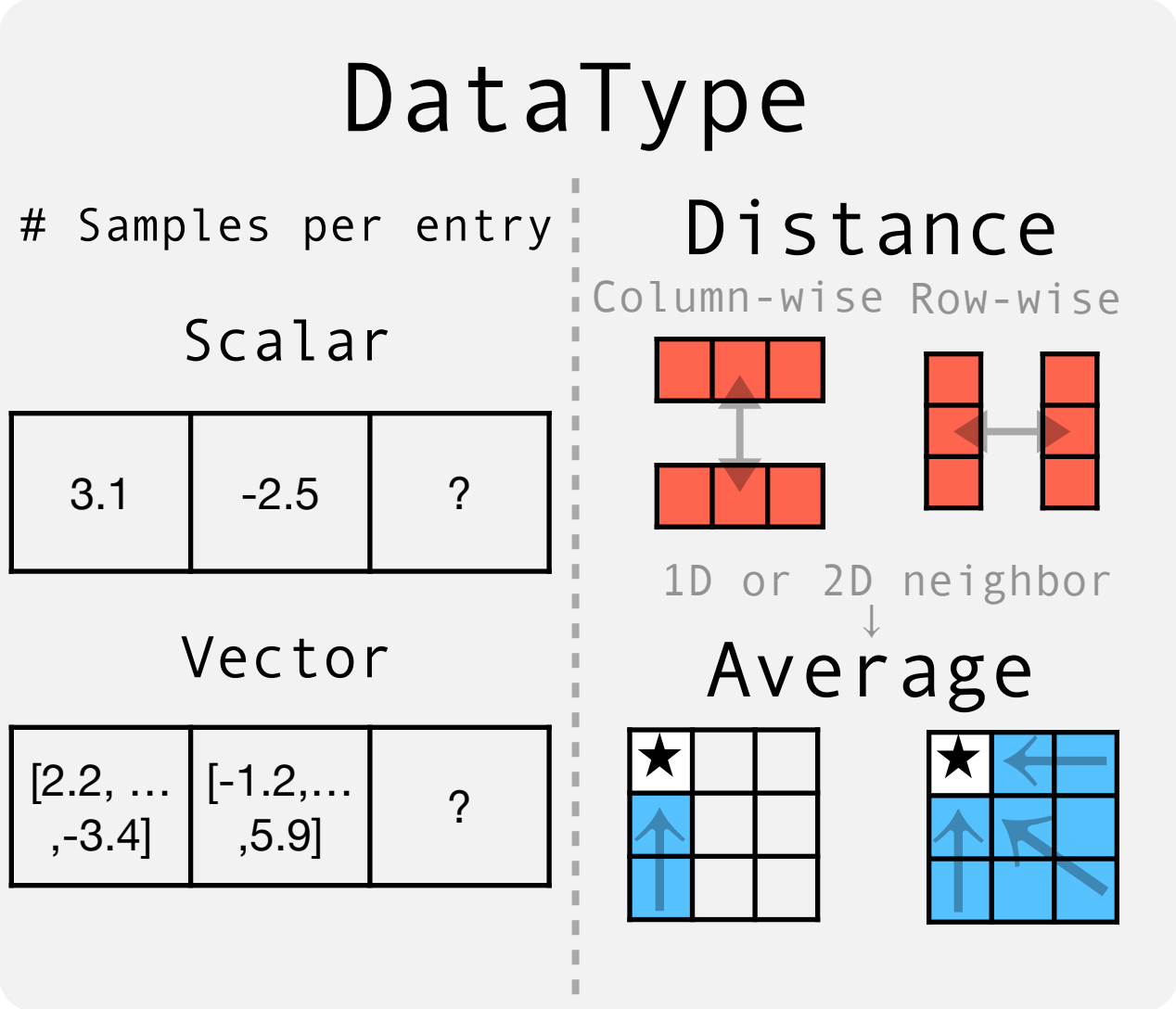CORNELL UNIVERSITY · IEOR · Wharton UNIVERSITY OF PENNSYLVANIA

Motivation

Nearest neighbor (NN) methods are effective tools for matrix completion but:

- A **unified framework** is needed to support rapid experimentation and development.

- **Standardized benchmarks** are needed for evaluating matrix completion methods across real-world scenarios.

Solution

N² is a **unified Python package** and **testbed** to:

- Consolidate a broad class of NN-based methods through a **modular, extensible interface**.

- Stress-test matrix completion methods on **diverse real-world datasets**, spanning healthcare, recommendation systems, causal inference, and LLM evaluation.
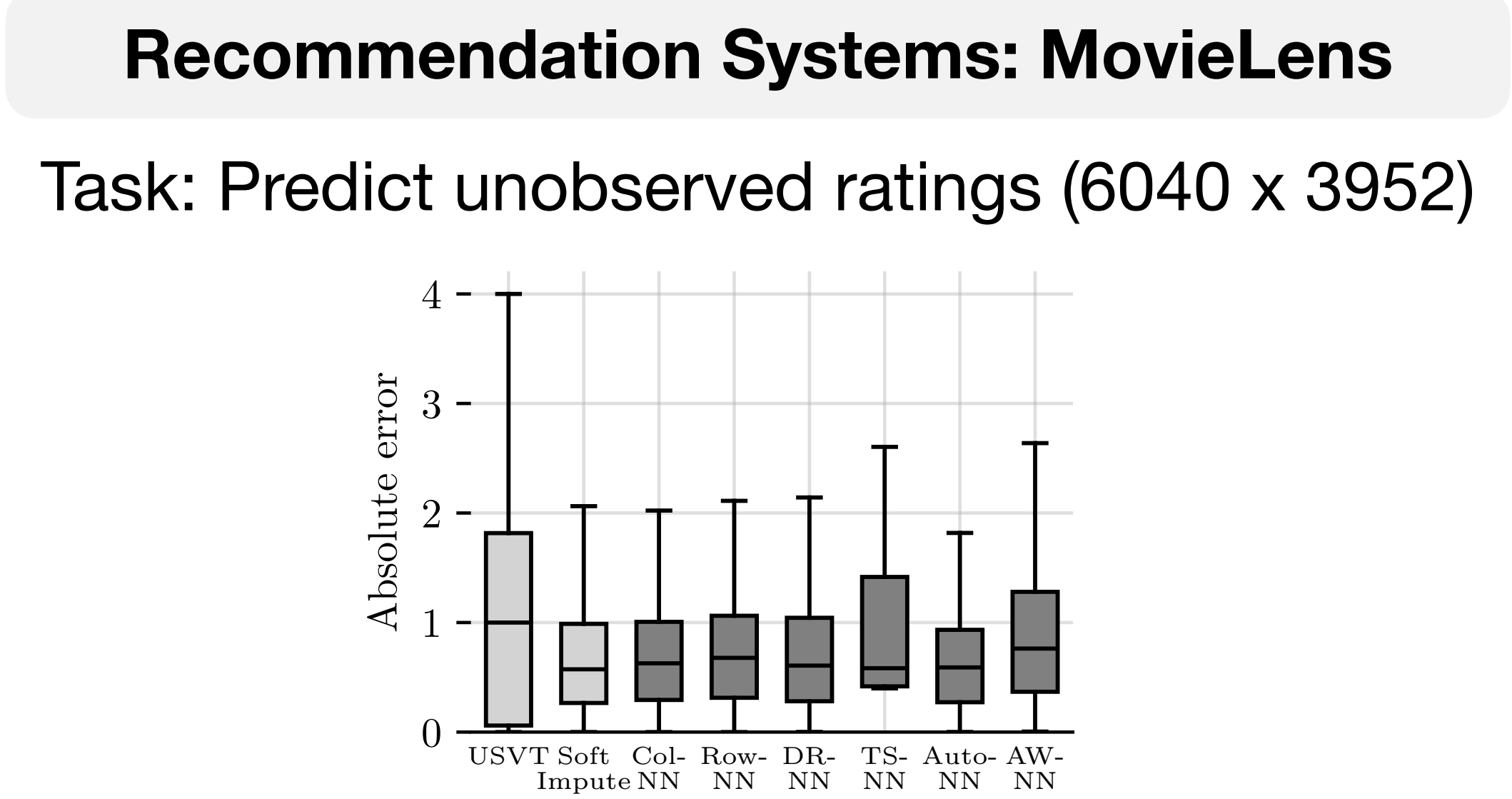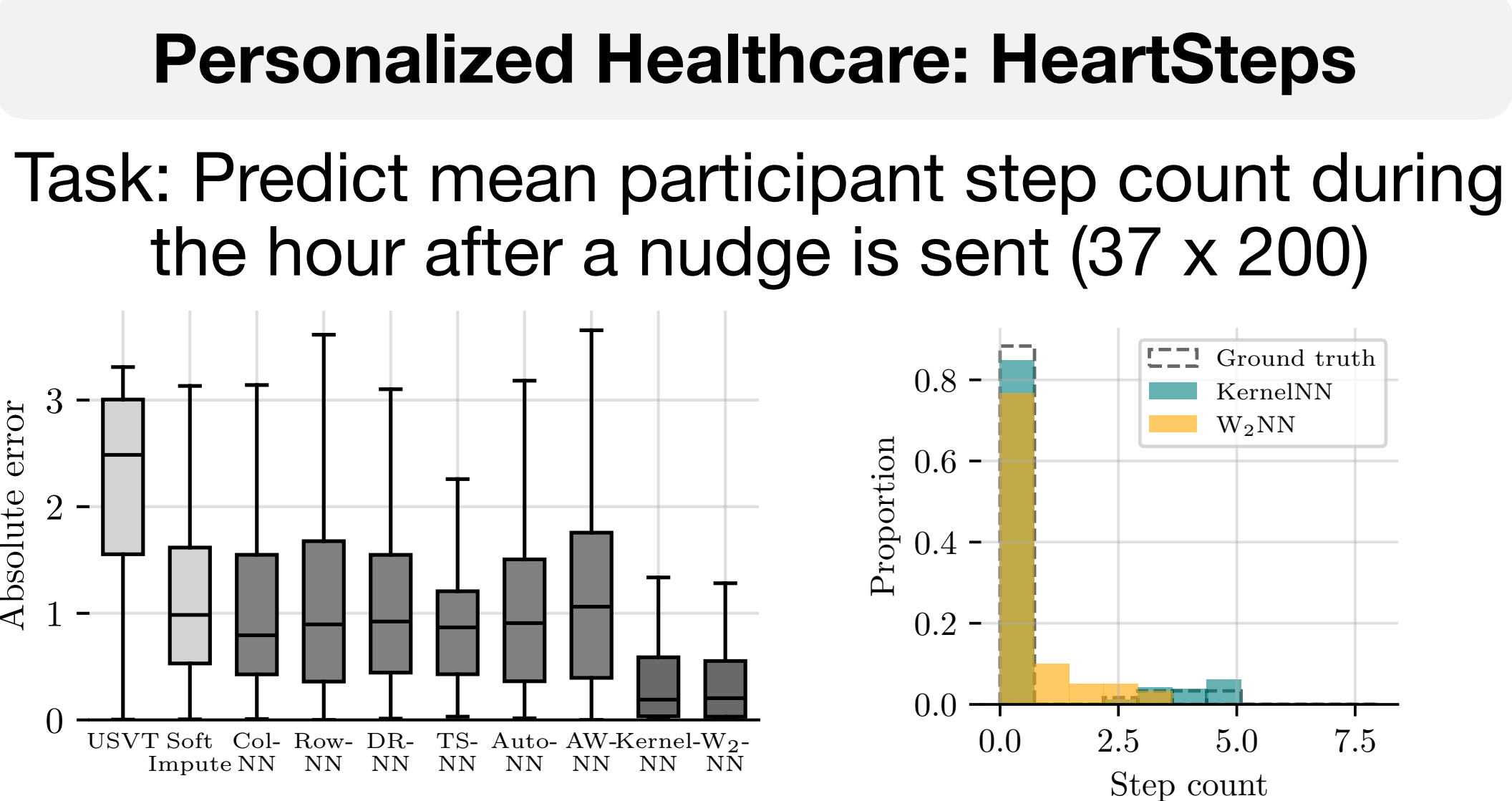
N² Framework

DataType

Samples per entry

Scalar

3.1	-2.5	?

Vector

[2.2, ... , -3.4]	[-1.2,... , 5.9]	?

Distance

Column-wise Row-wise

1D or 2D neighbor

Average

EstimationMethod

Column NN

Two-Sided NN

Doubly-Robust NN

$$\text{AutoNN} = \alpha\text{TSNN} + (1 - \alpha)\text{DRNN}$$

```python
from nsquared.estimation_methods import RowRowEstimator
from nsquared.data_types import Scalar
from nsquared.fitting_methods import LeaveBlockOutValidation

# Instantiate the NN modules
estimator = RowRowEstimator()
data_type = Scalar()
imputer = NearestNeighborImputer(estimator, data_type)

# Fit the NN threshold using cross validation
fitter = LeaveBlockOutValidation(
        block,
        distance_threshold_range=(0,1),
        n_trials=100,
        data_type=data_type
    )
fitter.fit(data, mask, imputer)

# Impute the (row, col) value given data and mask matrix
imputed_value = imputer.impute(row, col, data, mask)
```
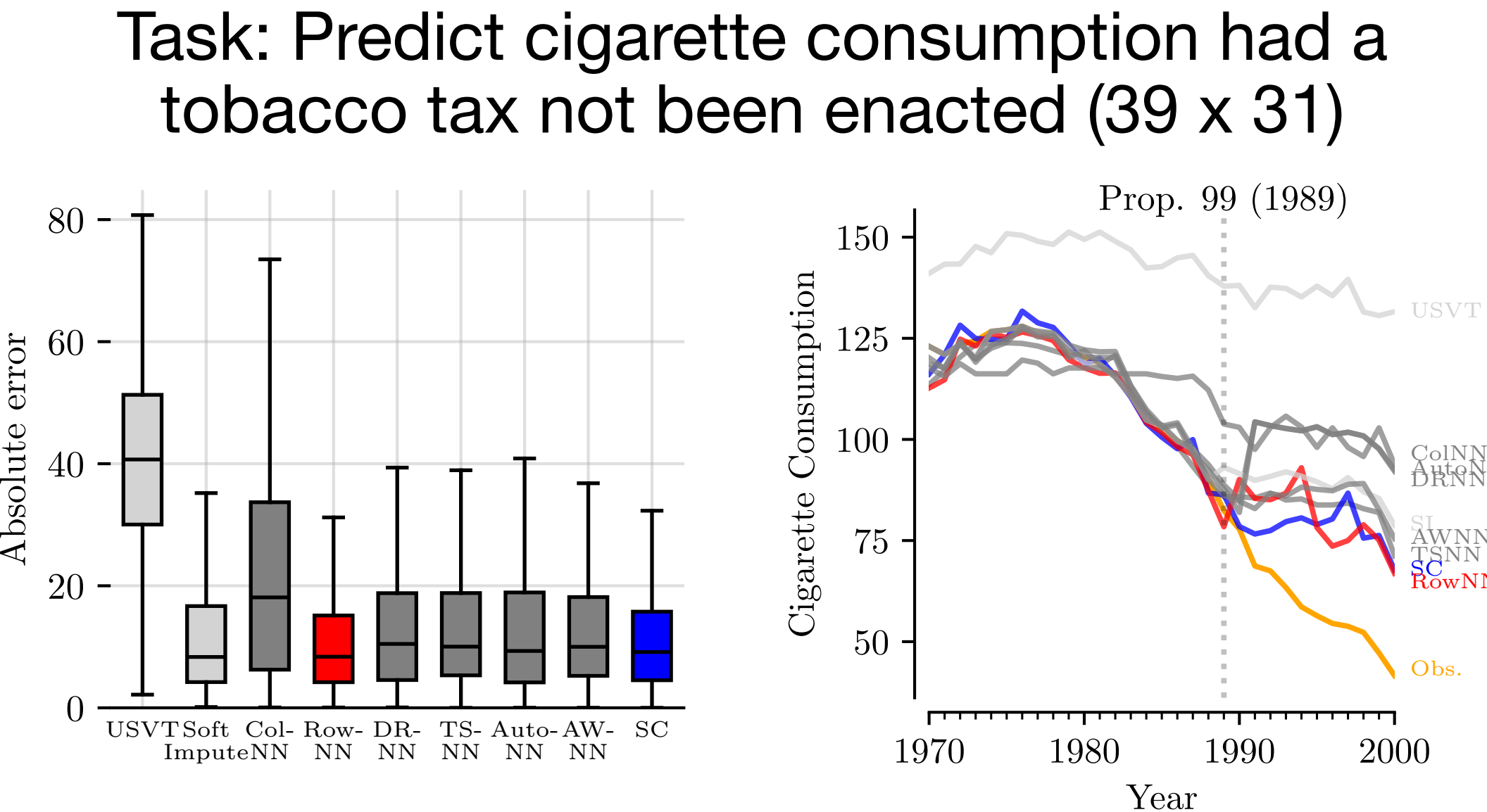
N²-Bench

Personalized Healthcare: HeartSteps

Task: Predict mean participant step count during the hour after a nudge is sent (37 x 200)

Recommendation Systems: MovieLens

Task: Predict unobserved ratings (6040 x 3952)

1. NN-based techniques perform on-par or better than classical methods in real-world scenarios.

2. N² and N²-Bench enable easy prototyping and benchmarking of new NN methods.

3. We introduce AutoNN, which adjusts to the underlying noise level and debiases automatically.

Counterfactual Inference: California Prop. 99

Task: Predict cigarette consumption had a tobacco tax not been enacted (39 x 31)

Efficient LLM Evaluation: PromptEval

Task: Predict model performance on MMLU tasks without performing all evaluations (15 x 57)