Lecture #13

Carnegie Mellon University

Special Topics:

Self-Driving Database Management Systems

Behavior Modeling I

@Andy_Pavlo // 15-799 // Spring 2022

LAST CLASS

We discussed Utah's query plan encoder paper.
→ It sort of was a workload / behavior modeling paper.

But it can only predict the behavior of queries based on high-level measurements (e.g., latency).

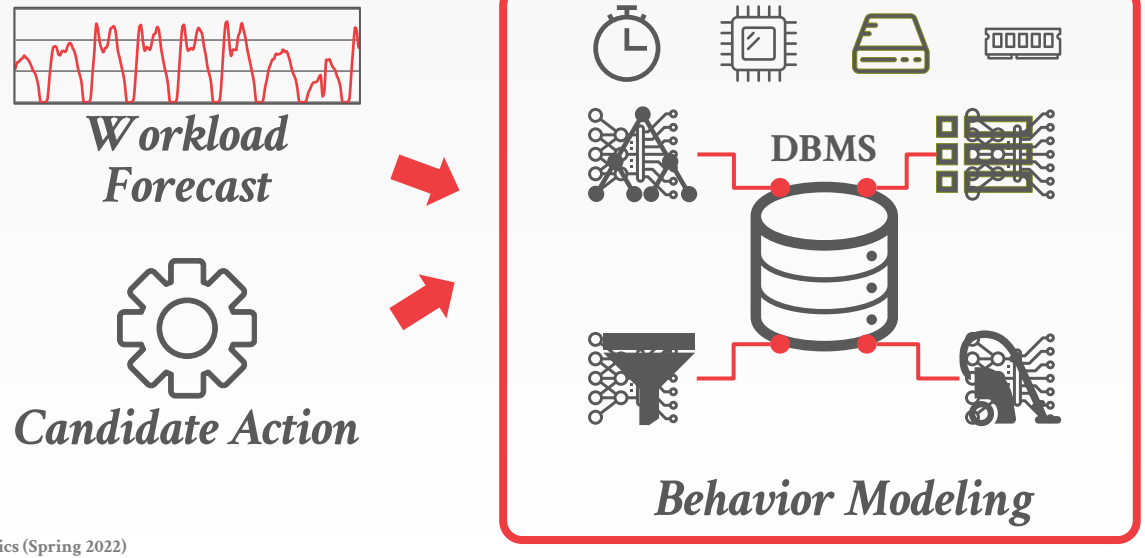
TODAY'S AGENDA

Behavior Modeling

Project #2 Topics

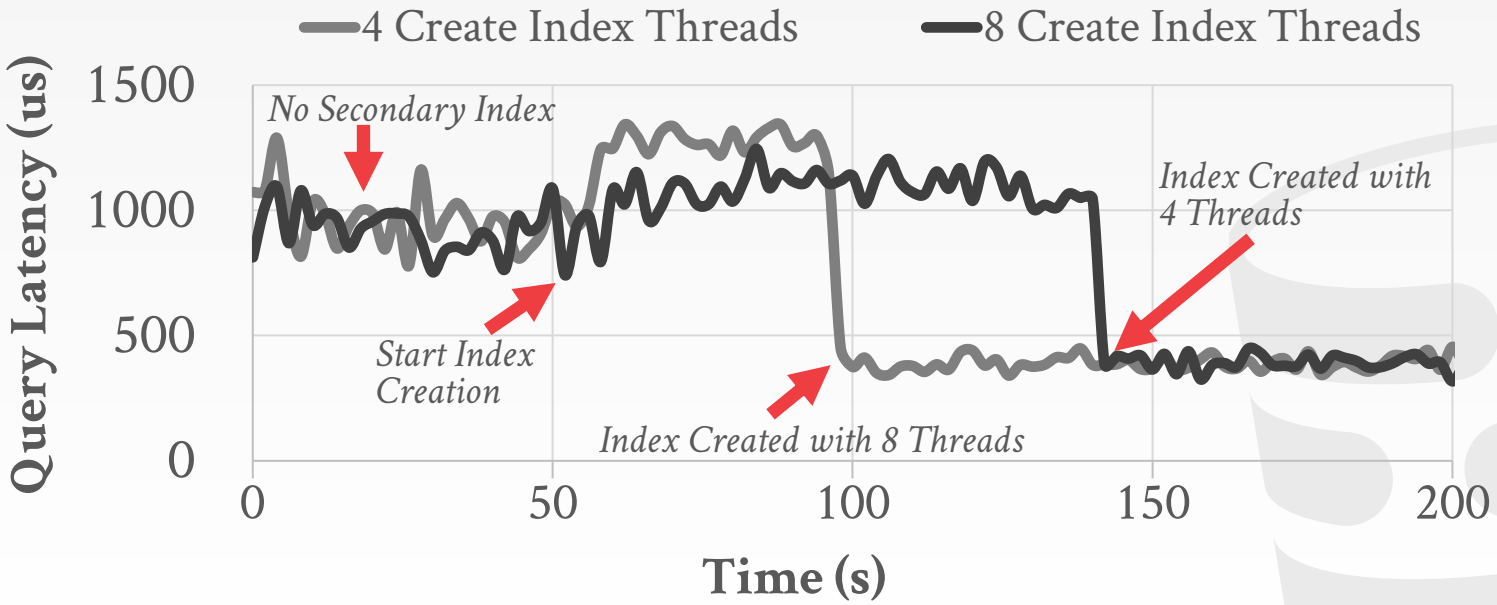
BEHAVIOR MODELING

Generate *behavior models* that predict the cost and benefit for self-driving actions.



MOTIVATION

Create an index with different number of threads.



Source: Lin Ma

CHALLENGES

High-dimensionality

Concurrent operations

Data collection and training

Interpretability, debuggability, and adaptivity

PREVIOUS SOLUTIONS

Analytical Models

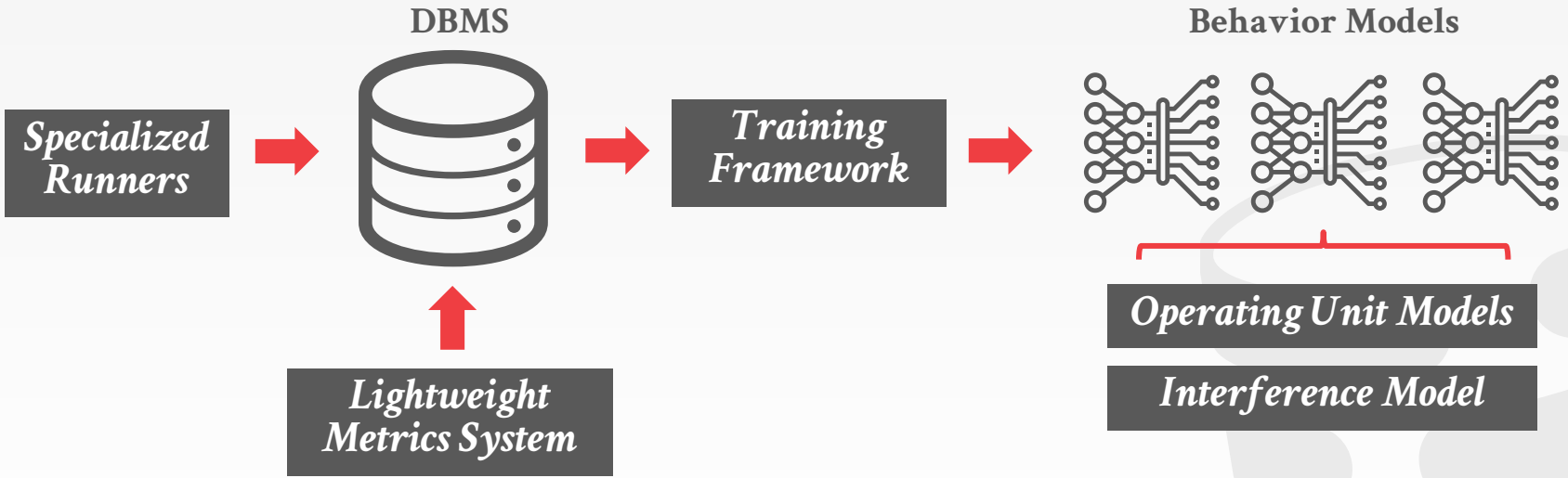
→ Onerous design from experts
→ Difficult to adapt

ML Models

→ Focus on single query execution
→ Difficult to generalize across databases

OFF-LINE BEHAVIOR MODELING

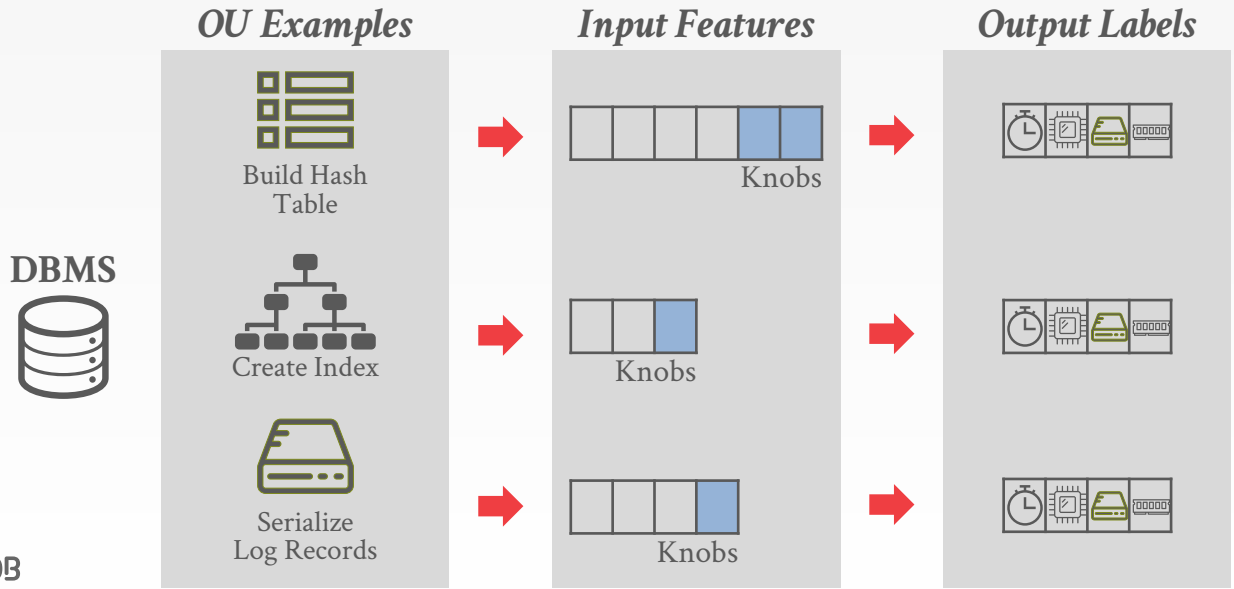
ModelBot 2 (MB2)



MB2: DECOMPOSED BEHAVIOR MODELING FOR SELF-DRIVING DATABASE MANAGEMENT SYSTEMS
SIGMOD 2021

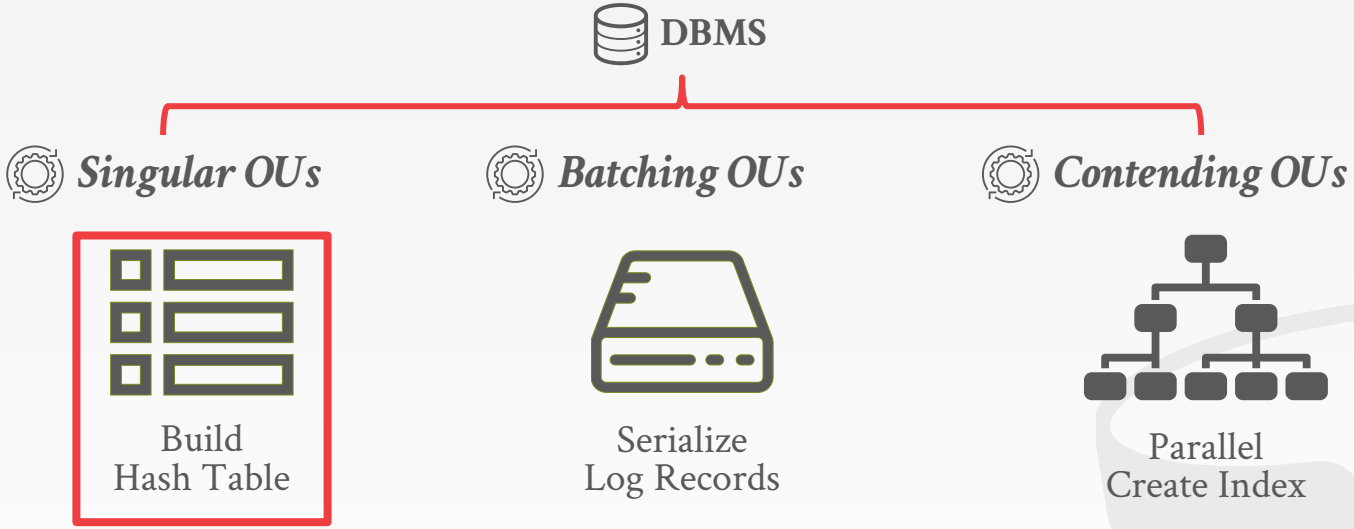
OPERATING UNIT MODELS

Decompose the DBMS into small operating units (OUs) to model separately.



Source: Lin Ma

OU CATEGORIES



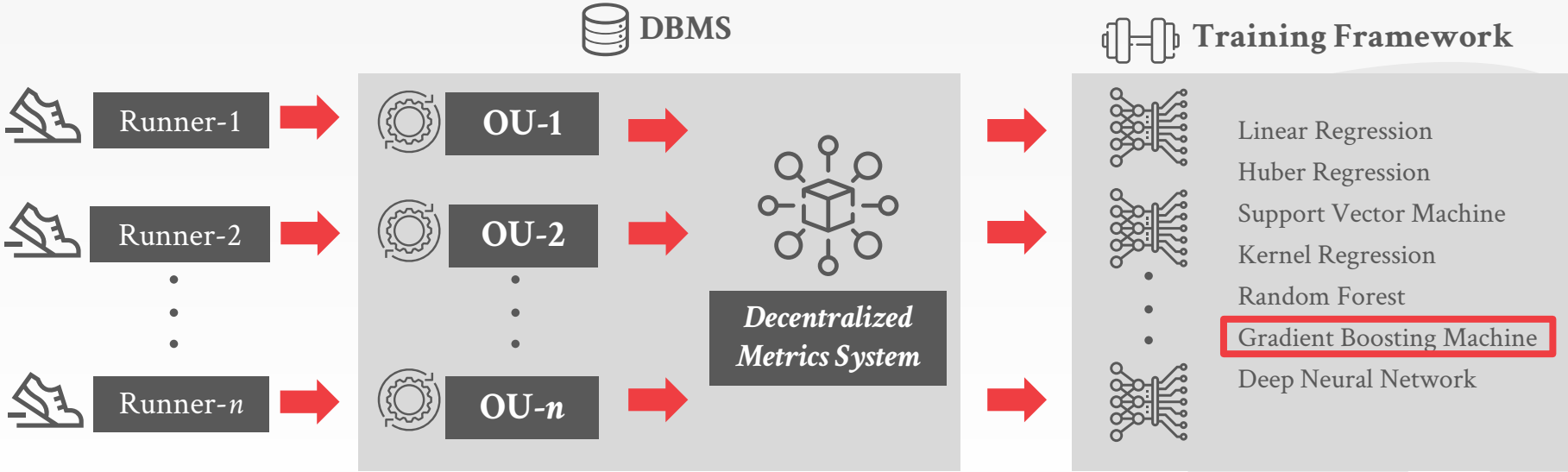
Input Features

(1) # rows
(2) # columns
(3) column size
(4) estimated cardinality
(5) related knobs

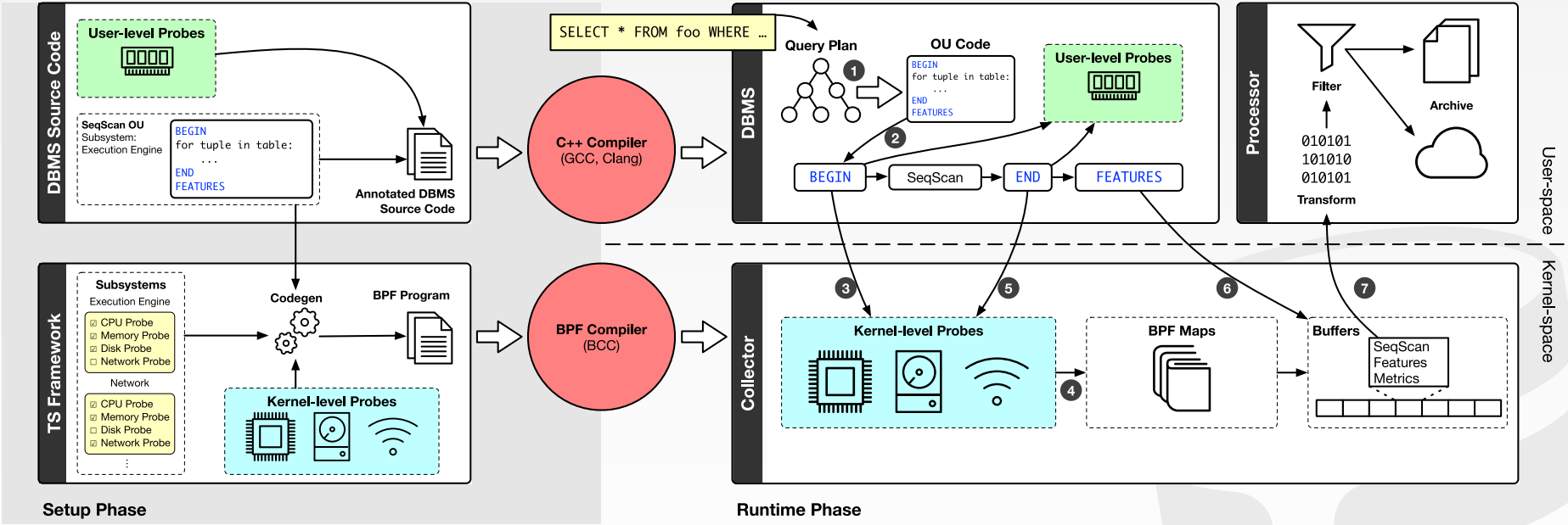
Must be able to derive all input features without executing query.

DATA COLLECTION & MODEL TRAINING

Specialized runners exercise each OU through SQL-based synthetic benchmarks.



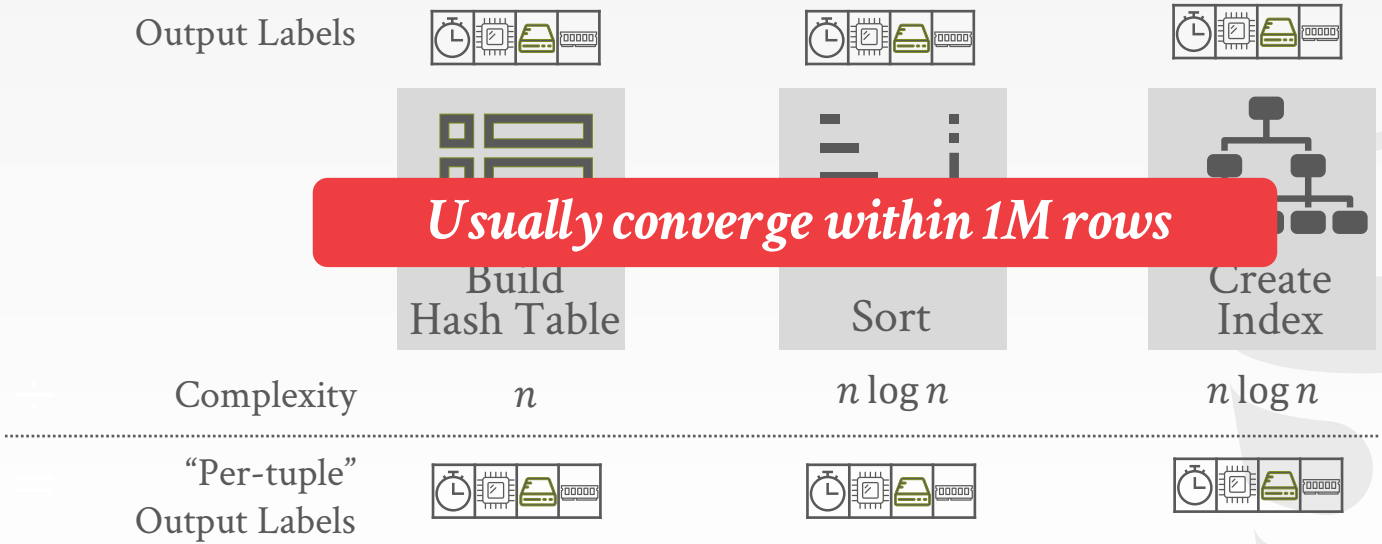
OU BOUNDARIES



TASTES GREAT! LESS FILLING! HIGH PERFORMANCE AND ACCURATE TRAINING DATA COLLECTION FOR SELF-DRIVING DATABASE MANAGEMENT SYSTEMS
SIGMOD 2022

OUTPUT NORMALIZATION

Training data for OUs may be expensive to collect.



ROBUST ESTIMATION OF RESOURCE CONSUMPTION FOR SQL QUERIES USING STATISTICAL TECHNIQUES
VLDB 2012

SINGLE-THREAD GENERALIZATION

Evaluate the accuracy of MB2's models for both OLAP and OLTP workloads:

→ Generalize to different scale factors or datasets

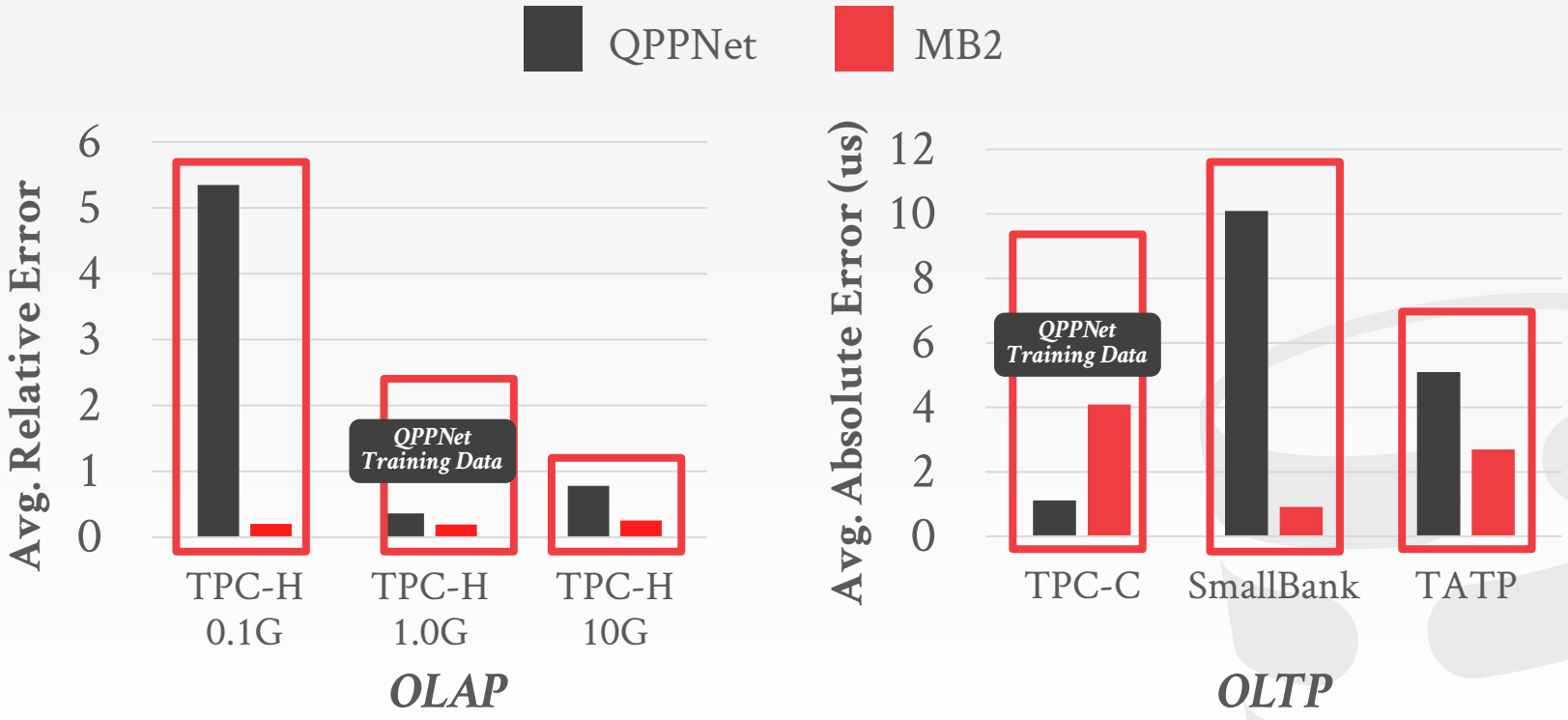
MB2 always uses the same OU models generated using off-line training data.

Comparison: **QPPNet**

→ Query plan-level modeling (Marcus et al., 2019)

→ Train on one workload, evaluate on others (without data generation mechanism)

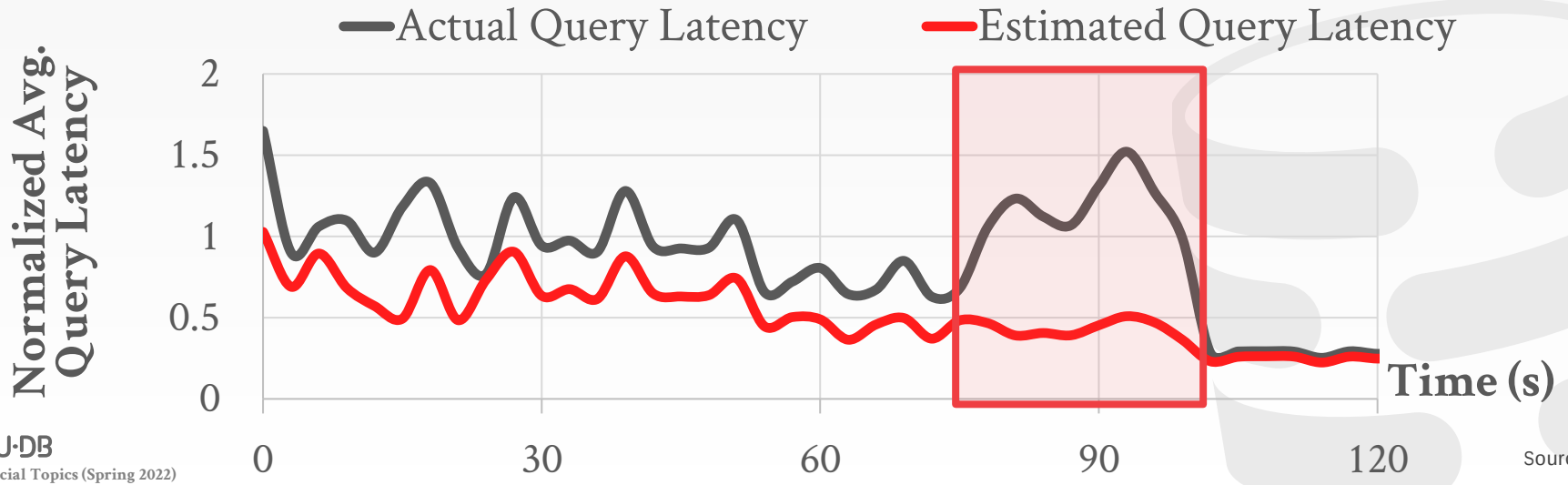
QUERY LATENCY PREDICTION



Source: Lin Ma

SINGLE-THREADED EVALUATION

Simulate a daily transactional-analytical cycle
→ Alternate between TPC-C and TPC-H
→ "Oracle" changes a knob for TPC-H and builds an index for TPC-C



Source: Lin Ma

INTERFERENCE MODEL

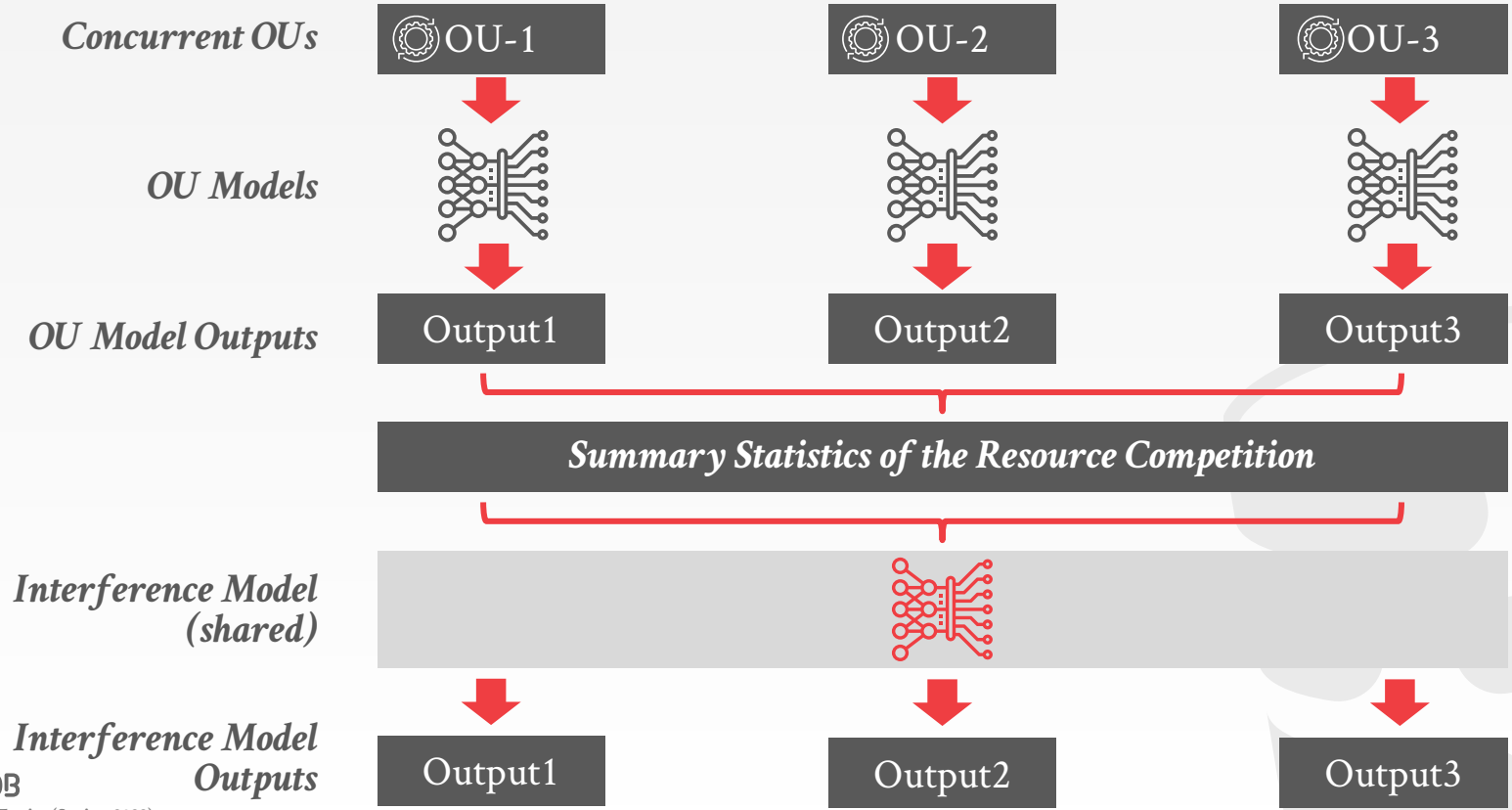
Use resource metrics from the OU-model outputs to approximate the interference.

→ **Input Features:** summary statistics of the OU-model outputs for concurrent OUs in a forecasting interval.

→ **Output Labels:** adjustment ratio based on the interference in system when executing workload.

Concurrent runners

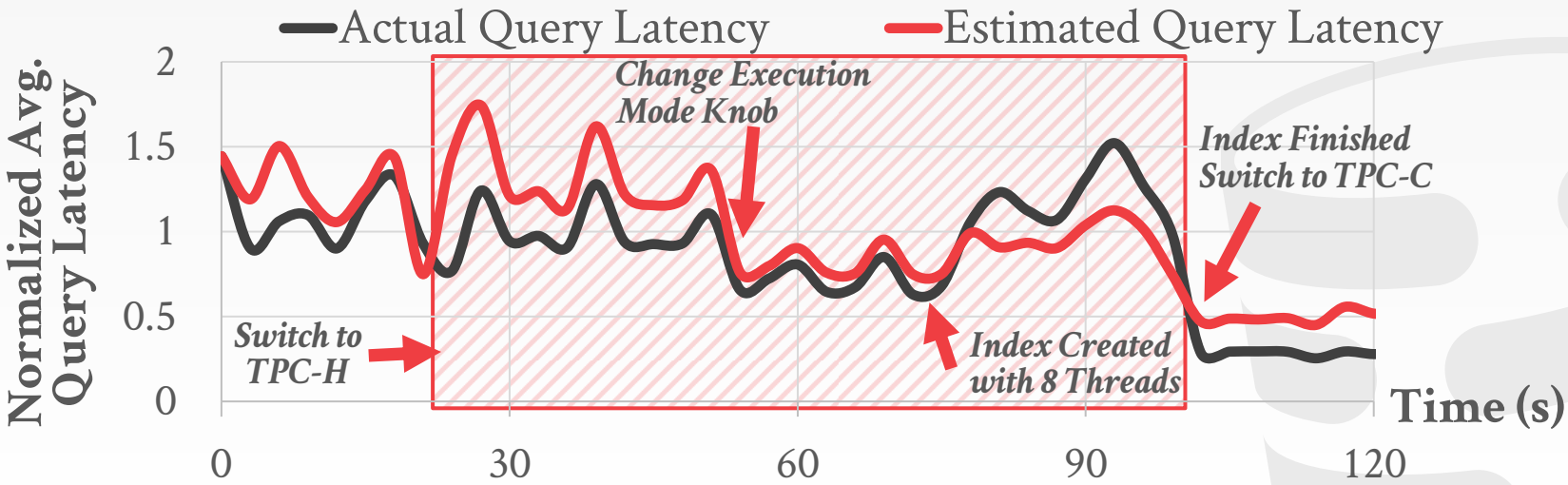
INFERENCE PROCEDURE



MULTI-THREADED EVALUATION

Start with TPC-C workload.

Switch to TPC-H workload after 25 seconds.



FUTURE WORK

May need to also instrument DBMS background tasks with OUs.

Automatically determine what input features to include per OU.

Automatically devise methods for collecting training data

→ Synthesize runners
→ Sweep workloads
→ Execute workload traces

PARTING THOUGHTS

Behavior modeling is a fundamental step towards building self-driving databases.

A decomposed behavior modeling framework with OU models and runners.

PROJECT #2

Each group (3-4 people) will choose a project that satisfies the following criteria:

→ Relevant to the materials discussed in class.
→ Requires a significant programming effort from all team members.
→ Unique (i.e., two groups cannot pick same idea).
→ Approved by me.

All projects will be based on the NoisePage Pilot with Postgres.

PROJECT #2

Project deliverables:

→ Proposal
→ Status Update
→ Design Document
→ Code Review
→ Final Presentation
→ Code Drop

Project #3

PROJECT #2 – PROPOSAL

10-minute presentation to the class that discusses the high-level topic.

→ **Date: Monday March 14th**

Each proposal must discuss:

→ Overall architecture and implementation timeline.

→ How you will test whether your implementation is correct.

→ What workloads you will use for your project.

PROJECT #2 – STATUS UPDATE

10-minute presentation to update the class about the current status of your project.

→ **Date: Monday April 11th**

Each presentation should include:

→ Current development status.
→ Whether your plan has changed and why.
→ Anything that surprised you during coding.

PROJECT #2 – DESIGN DOCUMENT

As part of the status update, you must provide a design document that describes your project implementation:

→ Architectural Design
→ Design Rationale
→ Testing Plan
→ Trade-offs and Potential Problems
→ Future Work

PROJECT #2 – CODE REVIEW

Each group will be paired with another group and provide feedback on their code.

Grading will be based on participation.

PROJECT #2 – FINAL PRESENTATION

10-minute presentation on the final status of your project during the scheduled final exam.

You should include any performance measurements or benchmarking numbers for your implementation.

Demos are always hot too…

PROJECT #3

A project is **not** considered complete until:

→ The code can merge into the main branch without any conflicts.
→ All comments from code review are addressed.
→ The project includes test cases that correctly verify that implementation is correct.
→ Source code contains clear documentation / comments.

Project #3 will be a class effort to merge all the projects together.

PROJECT TOPICS

Expanded OU Coverage

Async OU Features

Action Enumeration

Pilot Control Plane

Pilot Catalog

Workload Forecasting++

Metric Forecasting

EXPANDED OU COVERAGE

NoisePage's OU instrumentation currently only supports a subset of query plan operators. We want to also support OLAP workloads.

Project: Add additional markers to collect OU training data for all workloads in BenchBase.

→ William has made it easier to identify which queries are missing OU coverage.

ASYNC OU FEATURES

We collect OU input features immediately when encountering markers. But we may be able to delay collecting some features (e.g., query plan meta-data).

Project: Implement asynchronous feature collection for queries.

→ Coalesce features offline in training service

→ Must work with TScout + Hutch

ACTION ENUMERATION

We want a principled and maintainable way of defining rules to generate candidate actions without a cost model to evaluate in search process.

→ Not sure whether actions can also be ranked.

Project: Create a framework that emits actions.

→ Also maintain history of actions applied.

→ Talk with Mike about this.

PILOT CONTROL PLANE

Build communication channels between Pilot and other services (DBMS instances, ML components).

→ Pilot initiates internal commands.

→ Pilot maintains state about what commands it has sent to other nodes and stores their responses.

Project: Build it ☺

PILOT CATALOG

NoisePage generates lots of training data that are just written out files on local disk. We need a programmatic way on how services can track this data.

Project: Create the Pilot's internal catalog

→ You will want to work with the control plane group to decide the interfaces for storing / retrieving data files.

WORKLOAD FORECASTING++

Our re-implementation of QB5000 is limited.

Project:

METRIC FORECASTING

We need to predict additional information about the database state beyond expected workload.

→ Table growth

→ Internal metrics (e.g., dead tuples)

Project: Create a new service for collecting additional metrics from DBMS and then train forecast models for them.

→ We are considering switching to Stanford's NeuralProphet.

PROJECT #2 – NEXT STEPS

Select your team members

Discuss project topics

Meet with Andy (March 7 – 13)

Proposal Presentation (March 14)

I will update the course spreadsheet with dates/times to sign up for meetings.

NEXT CLASS

QPPNet Behavior Modeling