Self-Driving Databases: It All Starts with Workload Forecasting

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Managing the DBMS

- DBMSs are (more and more) complex and difficult to manage

- Personnel is estimated to be almost 50% of the total ownership cost of a DBMS
  - 73% DBAs think performance tuning occupies the most time

- Laborious, costly, difficult to scale
  - 72% DBAs manage increasing number of databases
Self-Driving Database

- A DBMS that can configure, tune, and optimize itself without any human intervention.
  - Will support: physical design, data placement, SQL tuning, knob configuration, provisioning
  - Will NOT support: security & ACLs, data integration, version control

- Why possible?
  - More Data (for DBMSs)
  - Better Hardware
  - Advances in AI/ML
Self-Driving Components

Perception → Action Model → Planning

Car:
Self-Driving Components

**Perception**
- Workload forecasting

**Action Model**
- Build indexes, change knobs, ...

**Planning**
- Best sequence of actions

DBMS:
First Step Towards Self-Driving Databases

Workload Forecasting

Indexing

Partitioning

Scaling

ORACLE AUTONOMOUS DATABASE

Azure Automatic Index Management
Workload Forecasting

- When, how many, and what queries will arrive

**Goals:**
1. Good Accuracy
2. Major Patterns
3. Cost vs. Accuracy

**Prediction Horizon**

**Prediction Interval**
Challenges

- On-line, Dynamic
- Large Query Volumes
- Different Arrival Rate Patterns

App #1

Queries / h

9-Jan 11-Jan 13-Jan 15-Jan 17-Jan

Cyclic (Diurnal)

App #2

Queries / h

21-Nov 28-Nov 5-Dec 12-Dec 19-Dec

Growth and Spike
QueryBot 5000

Application SQL DBMS Large Historical SQL Forecasts QB 5000 SQL Forecasts Compact Predictive Action Model Planning

#1 - Pre-Processor
#2 - Clusterer
#3 - Forecaster
Step #1 - Pre-Processor

- Templatization

```
SELECT * FROM foo WHERE id = Percona
```

- Semantics equivalence check

```
SELECT a, b FROM foo
```

```
SELECT b, a FROM foo
```

Distribution Matters

Millions $\rightarrow$ Thousands
Step #2 - Clusterer

- Possible Similarity Features
  - Physical Feature
  - Logical Feature
  - Arrival Rate Feature

![Diagram](image)
Arrival Rate History

- Template 1
- Template 2
- Template 3
- Cluster Average

Queries/h

26-Dec  28-Dec  30-Dec  1-Jan  3-Jan  5-Jan

Bus Tracking App
Coverage of the Largest Clusters

A few large clusters exhibit major patterns
Step #3 - Forecaster

- Different models have different properties
  - Linear Regression (LR), ARMA, Kernel Regression (KR), Recurrent Neural Network (RNN), FNN, PSRNN
  - Properties: Linear, Memory, Kernel

- **Ensemble Method**: combine different models

*LR+RNN has the best average accuracy*
Prediction Results

1 Hour Horizon:

1 Week Horizon:

Queries / h

Actual
Predict

x 10000

9-Jan 11-Jan 13-Jan 15-Jan 17-Jan
Prediction Results for Spikes

ENSEMBLE: (LR+RNN)

Kernel Regression (KR):

Admissions App 1 Week Horizon
HYBRID Model

ENSEMBLE: (LR+RNN)

HYBRID: (LR+RNN+KR)

Queries / h

Actual
Predict

x10^6

Admissions App
1 Week Horizon

21-Nov 1-Dec 11-Dec 21-Dec
Rudimentary Self-Driving Database

- An auto-indexing prototype for MySQL
- Start with only primary indexes
- Off-the-shelf index suggestion algorithm to build 20 indexes in two settings
  - RETROSPECT (Baseline): Build all indexes at beginning with sample history
  - PREDICT: Build indexes one new index at every fixed interval using the forecasting
Automated Indexing Building

- Add Index
- Retrospect
- Predict

Queries/s

6:00 9:00 12:00 15:00 18:00 21:00
0 3000 6000 9000

25%
Beyond Rudimentary Self-Driving Database

- Missing good planning
- Required information:
  - The impact if the new index is *built*
  - The impact while *building* the index

New Index | Benefit/Penalty | Deployment
---|---|---
| Faster Access | CPU Cost |
| Update Cost | Duration |

*Traditionally estimated by human*
Self-Driving Components

Perception

Action Model

Planning

DBMS:

- Workload forecasting

- Build indexes, change knobs, ...

- Best sequence of actions
Example: Index Deployment Speed

- Varying key size and number of threads, fixing other factors

BwTree, Varchar Key, Same Hardware
Preliminary Prediction Result

- Predict the deployment speed on other key sizes

Polynomial Regression (Degree 4)
On-going Work

- Extend the model of index creation to include other factors

- Similarly, model the behavior of other actions
  - Changing knobs, scaling resources, workload control, etc.
Self-Driving Components

**Perception**
- Workload forecasting

**Action Model**
- Build indexes, change knobs, ...

**Planning**
- Best sequence of actions
Mountain View’s Peloton announces truck platooning partnership

terrier

You know what this is...
Takeaways

- Workload forecasting for self-driving DMBS on combinations of horizons/intervals

- Reduce the forecasting cost with minimal lost of accuracy

- Hybrid forecasting method

- Building action models for better planning

- Early results are promising, lots of remaining challenges
END
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