Automatic Database Management System Tuning Through Large-scale Machine Learning

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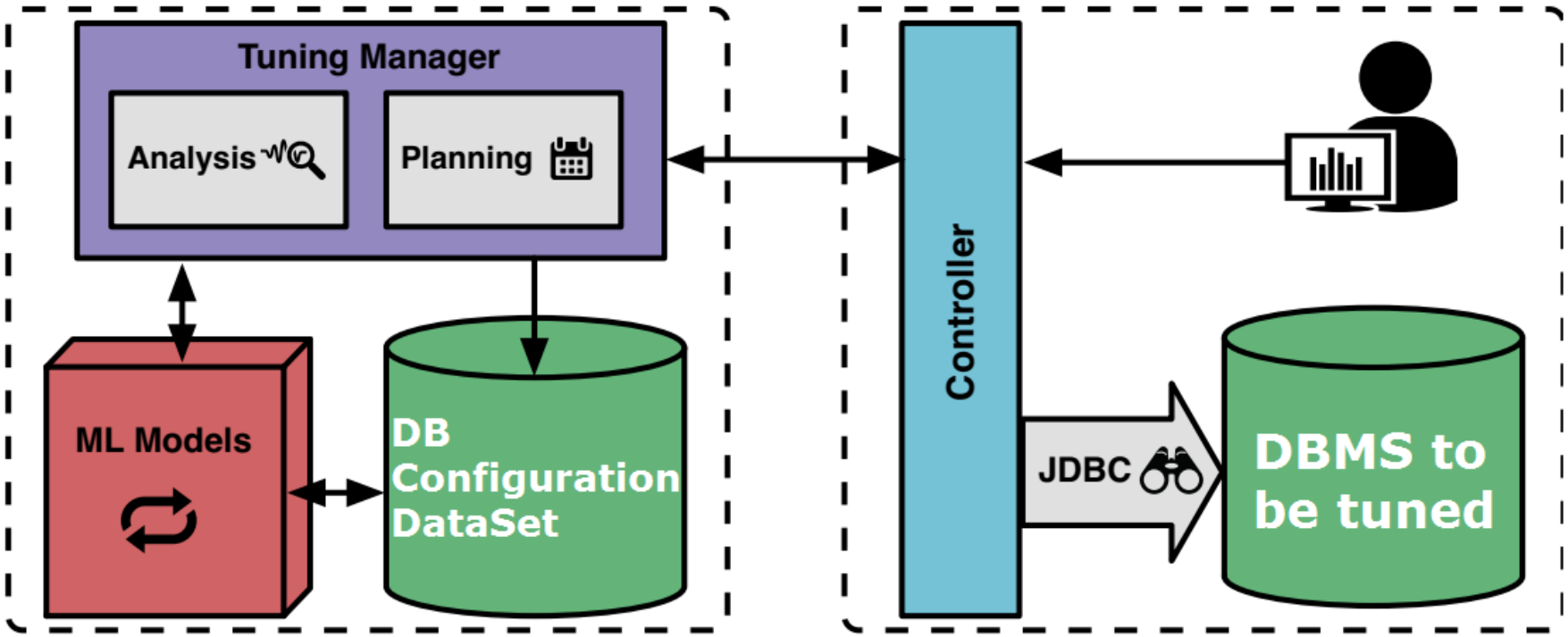
Weakness in manually DBMS tuning

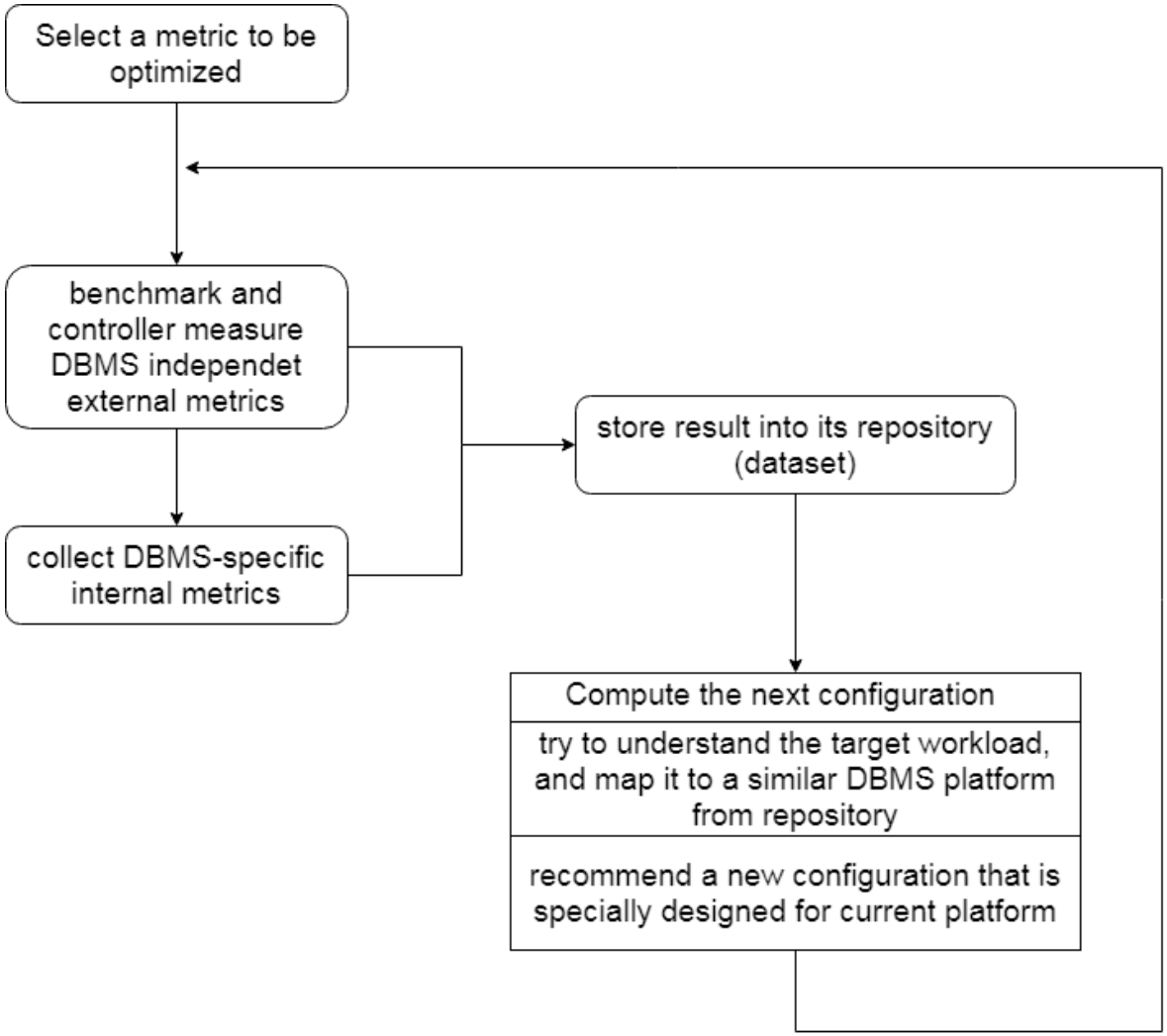
- Dependencies between different knobs
- Changing of performance is irregular
- Configurations depend on specific platform
- Tuning Complexity

- -> how to tune DBMS automatically?

OtterTune: an automatic tuning system



OtterTune: an automatic tuning system



Workload characterization

- To discover a model that could identify which previously seen workloads in the repository are similar to target workload.

- Use DBMS's internal runtime metrics to characterize workload.

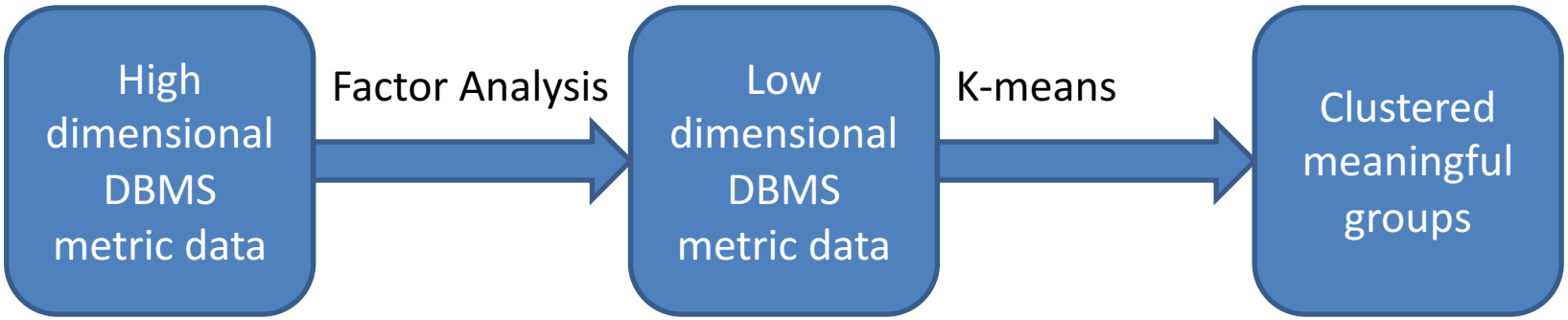
- Cons:
  - Accurate
  - Could be directly affected by knobs' settings

Workload characterization

- 1. Collect DMBS runtime statistics
- Save as K/V pairs in its repository
- Limitation: only consider global knobs

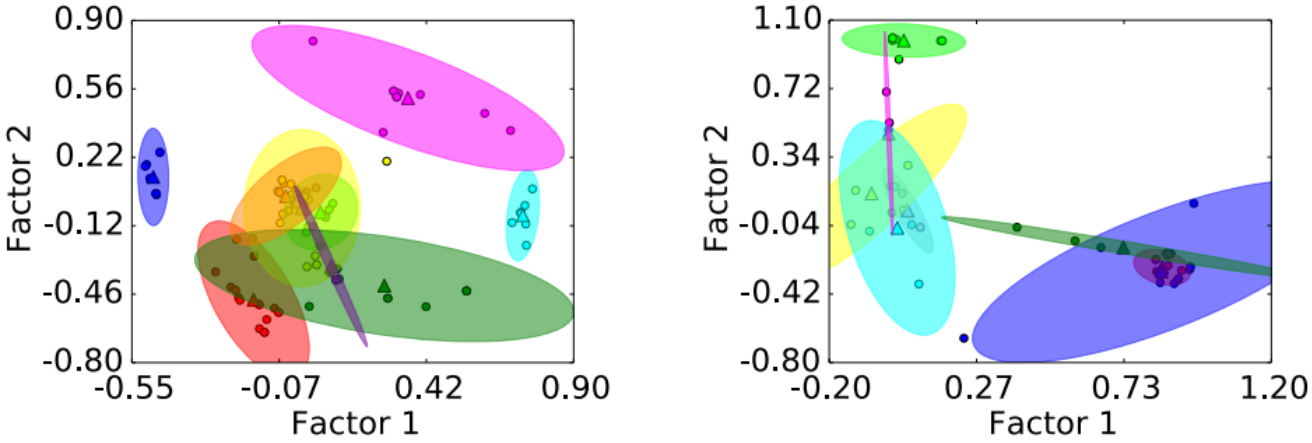
Workload characterization

- 2. Remove redundant metrics in order to reduce the search space of ML algorithms



Workload characterization

- 2. Remove redundant metrics in order to reduce the search space of ML algorithms
- The one closet to cluster center as the representation of all metrics in this cluster



(a) MySQL (v5.6) **(b)** Postgres (v9.3)

Figure 4: Metric Clustering – Grouping DBMS metrics using k-means based on how similar they are to each other as identified by Factor Analysis and plotted by their (`f1`, `f2`) coordinates. The color of each metric shows its cluster membership. The triangles represent the cluster centers.

Identify important knobs

- Identify which knobs have the strongest impact on the target objective function.
- Use *Lasso*, a feature selection technique for linear regression, to expose the knobs that have strongest correlation to the system's overall performance.

Identify important knobs

- Feature selection with Lasso: a Linear regression method
- Cost function: $J(w) = \frac{1}{m}\sum_{i=1}^{m}\left(y_i - w^T x_i\right)^2 + \lambda\|w\|_1 \, (\lambda > 0)$
- *X: DBMS's knobs*
- *Y: metrics collected during observation period*

- Use *Lasso Path Algorithm* to determine the order of importance of the DBMS knobs (Appendix A)

Automated tuning

- STEP1 Workload Mapping
- Find a workload in its repository which is most similar with the target DBMS's workload
- For each metric, build a matrix from the data in repository

```
S[num_of_metrics][num_of_workload][configuration]
S[m][i][j] == The value of metric m observed when executing
workload i with configuration j
```

- Workload mapping: by calculating Euclidean distance(ED[m][i]) between the vector of measurements for target workload and each S[m][i]
- Score of workload i = Average(ED[m][i] for each m), and select the workload with minimum score

Automated tuning

- STEP2 Configuration recommendation
- Use Gaussian Process regression
- Find the best configuration in each observation period by choosing the strategy with the greatest expected improvement
  - (1) *exploration:* searching an unknown region in its GP(workloads with little to no data)
  - (2) *exploration:* selecting a configuration that is near the best configuration in its GP

Experimental evaluation

- 1. Platform
- OLTP workloads:
  - DBMS: MySQL, Postgres
  - Workloads: YCSB, TPC-C, Wikipedia
  - 5-minute observation periods
  - Target metric : 99%-tile latency
- OLAP workloads:
  - DBMS: Active Vector
  - Workloads: TPC-H
  - Variable-length(total exec time) observation periods
  - Target metric : total exec time of the workload

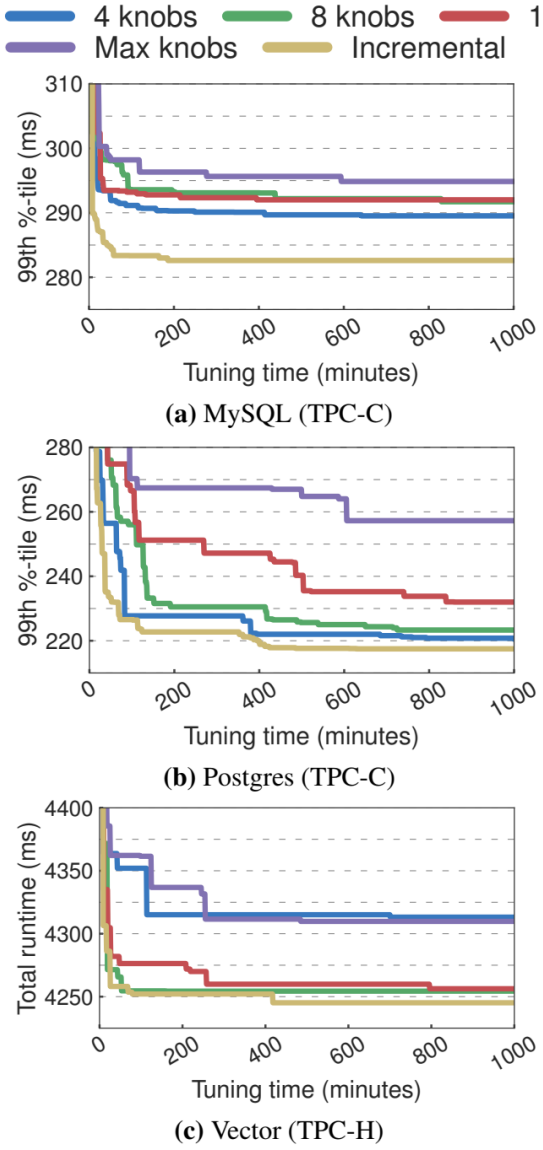
Experimental evaluation

- 2. Generate initial training data in repository
- Workloads: Permutations of YCSB and TPC-H
- Knobs configurations: random values within valid range
- Execute over 30k experiments on each DBMS with different workload and knob configurations.

Experimental evaluation

- 3. Analysis of OtterTune when optimizing different numbers of knobs
- To prove that OtterTune can identify the appropriate number of knobs to be tuned. (balance between DBMS performance and tuning complexity)
- 2 settings: fixed number of knobs && increase the number of knobs gradually

Experimental evaluation

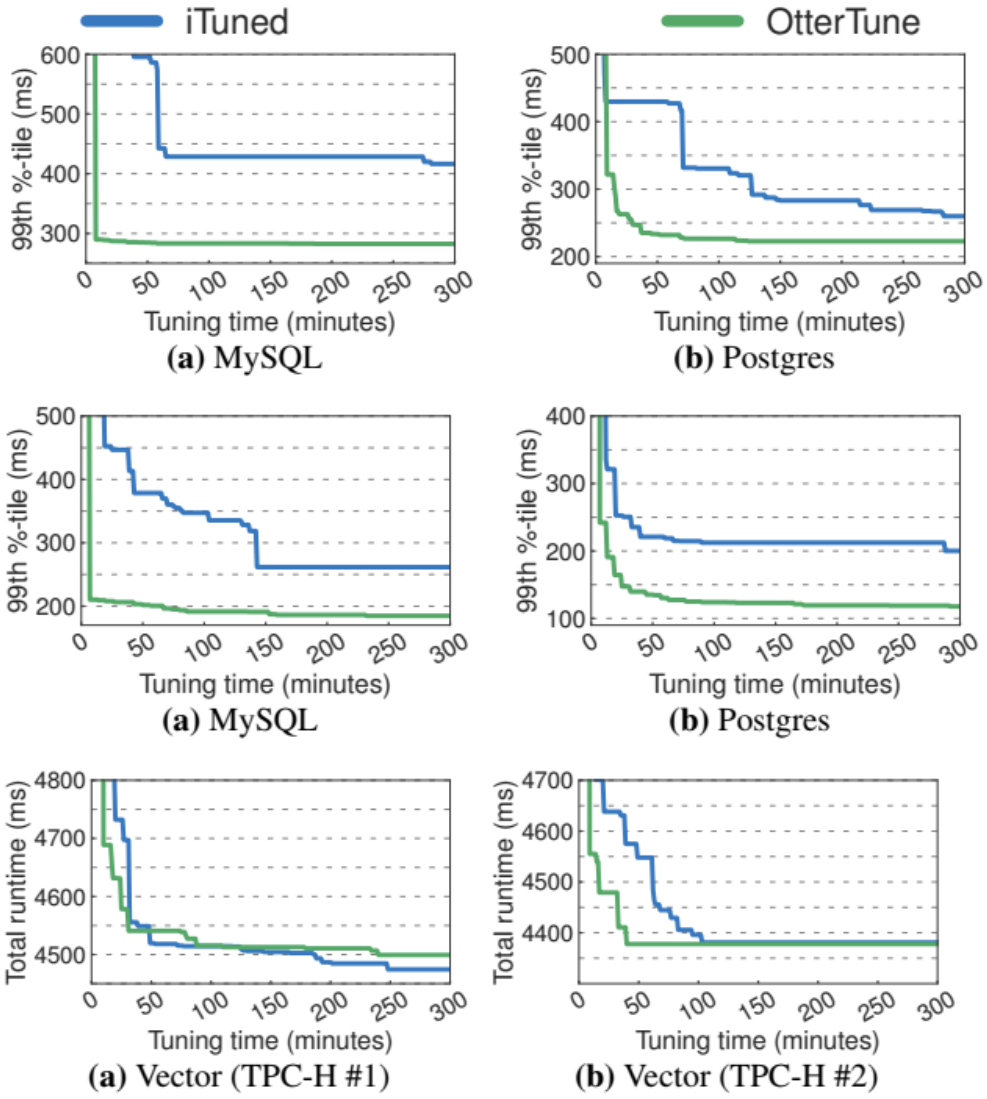


- 3. Analysis of OtterTune when optimizing different numbers of knobs
- A: MySQL + TPC-C
  - Incremental method is the best
  - Larger number of knobs have little improvement
- B: Postgres + TPC-C
  - Incremental method and 4 knobs are the best
  - Incremental method allows exploring and optimizing the configuration space for a small set of the most impactful knobs, before expanding its scope to consider the others
- C: Vector + TPC-H
  - Incremental method, 8 knobs, and 16 knobs are the best
- Incremental method is the best approach

Experimental evaluation

- 4. Show how learning from data in repository(previous tuning sessions) improve OtterTune's ability to find a good knob configuration
- Compare with another tool "iTuned"
- OtterTune: trains its GP models using the data from the most similar workload mixed with the data determined in the last workload mapping stage. Use incremental method.
- iTuned: does not train its GP models using data collected from previous tuning sessions (The initial configuration is generated by a stochastic sampling technique). It start use incremental knob only after running initial set of experiments.

Experimental evaluation



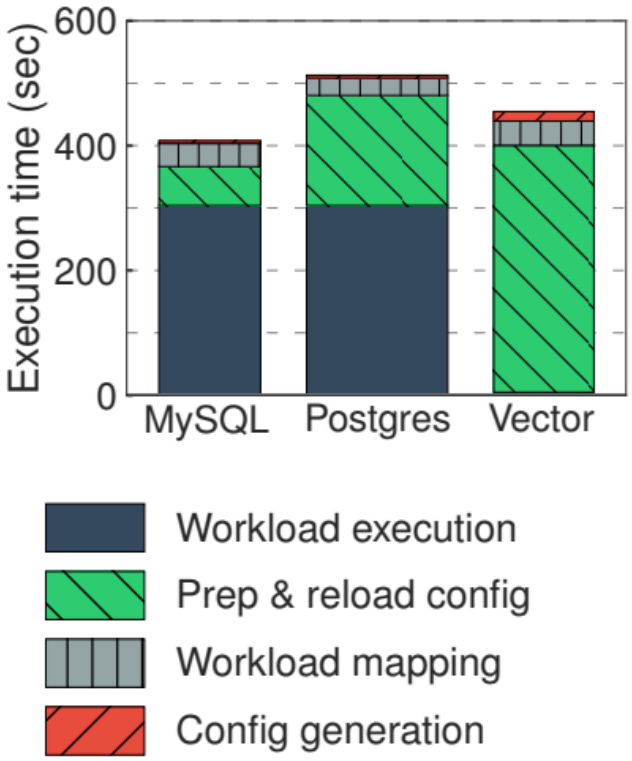
- 4. Show how learning from data in repository(previous tuning sessions) improve OtterTune's ability to find a good knob configuration
- A: TPC-C
  - OtterTune find better configuration in less time
  - Trained GP model in OtterTune have a better understanding of the configuration space
- B: Wikipedia
  - OtterTune achieved lower latency.
- C: TPC-H
  - OtterTune achieved lower latency

Experimental evaluation

- 5. Analysis the amount of time that OtterTune spends in the different parts of its tuning algorithm

- **Workload Execution**: The time that it takes for the DBMS to execute the workload in order to collect new metric data.
- **Prep & Reload Config**: The time that OtterTune's controller takes to install the next configuration and prepare the DBMS for the next observation period (e.g., restarting if necessary).
- **Workload Mapping**: The time that it takes for OtterTune's dynamic mapping scheme to identify the most similar workload for the current target from its repository. This corresponds to Step #1 from Sect. 6.1.
- **Config Generation**: The time that OtterTune's tuning manager takes to compute the next configuration for the target DBMS. This includes the gradient descent search and the GP model computation. This is Step #2 from Sect. 6.2.

Experimental evaluation



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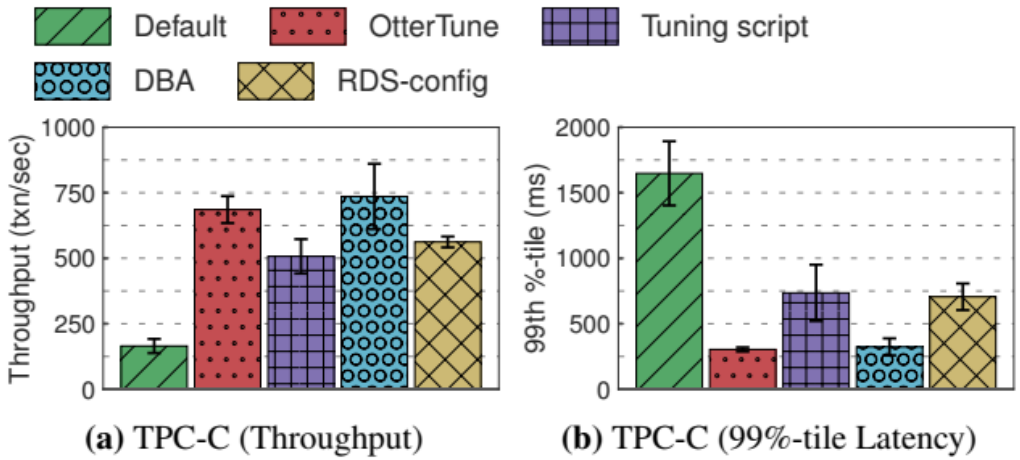
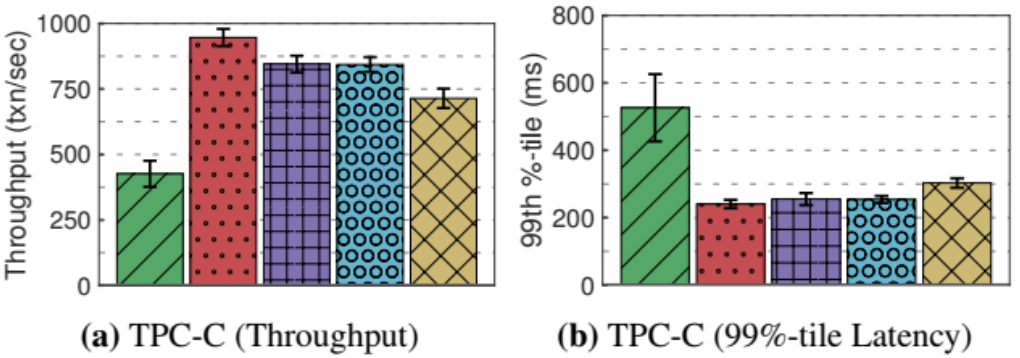
Experimental evaluation





- 6. Compare the configuration generated by OtterTune with the one provided by human DBA, open-source tuning advisor tools, and cloud DBaaS provider(Amazon RDS).

Future Work

- Hardware capabilities
- Turning component-specific knobs
- Max num of log files in Sec7.6 (optimize several metrics simultaneously)
- Online training without the type of workload specified