School of Information Technology

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Project Report

Benchmarking Graph Databases: Neo4j vs ArangoDB vs MongoDB vs OrientDB

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ITEC6220 M - Advanced Information Management (Winter 2018-2019)

Instructor: Prof. Xiaohui Yu

2019.04 v2.1

It’s All about Performance

We are using the same datasets, same query workload, and same environment cross validation of result each graph database's benchmark.

- Orientdb Community Edition 3.0.17
- Neo4j Community Edition 3.4.12
- ArangoDB Community Edition 3.4.4
- MongoDB Community Edition version v4.0.8

Contents

Summary of the Research

(1) The highly-connected structure of many natural phenomena, such as road, biological, and social networks make graphs an obvious choice in modelling.

(2) We notice the who-trusts-whom network of people who trade using Bitcoin on a platform called Bitcoin OTC.

(3) The following queries are commonly used, Create, Read, Update, and Delete (CRUD) operations

(4) Graph databases are used for Shortest Path (such as Dijkstra's algorithm)[1] is an algorithm for finding the shortest paths between nodes in a graph, which may represent, for example, road networks, users' ratings.

Summary of the Research cont’d

- For comparison, we only used the leading graph database systems. We selected operational graph databases (OrientDB and Neo4j) and Multi-Modal Graphs (ArangoDB, MongoDB) (Datanami, A Look at the Graph Database Landscape, Yu Xu, November 30, 2017)
- We benchmarked them to against each other
- In the application domains where relationships are of importance, GDBMS increasingly gains popularity since the relationships can be explicitly modeled and easily visualized in a graph data model.

Summary of the Research cont'd

To select a standard dataset we decided to use Bitcoin OTC trust weighted signed network:

S. Kumar, F. Spezzano, V.S. Subrahmanian, C. Faloutsos. Edge Weight Prediction in Weighted Signed Networks. IEEE International Conference on Data Mining (ICDM), 2016.
S. Kumar, B. Hooi, D. Makhija, M. Kumar, V.S. Subrahmanian, C. Faloutsos. REV2: Fraudulent User Prediction in Rating Platforms. 11th ACM International Conference on Web Searchand Data Mining (WSDM), 2018.

Summary of the Research cont'd

As an addition, full-text search is important for most of the databases. We choice Infrastructure Canada data (10M, consider we are running a free VMs)

This dataset contains a list of infrastructure projects across Canada that have been approved by Infrastructure Canada. The project information listed is based on current information.

Research Motivation and Aim

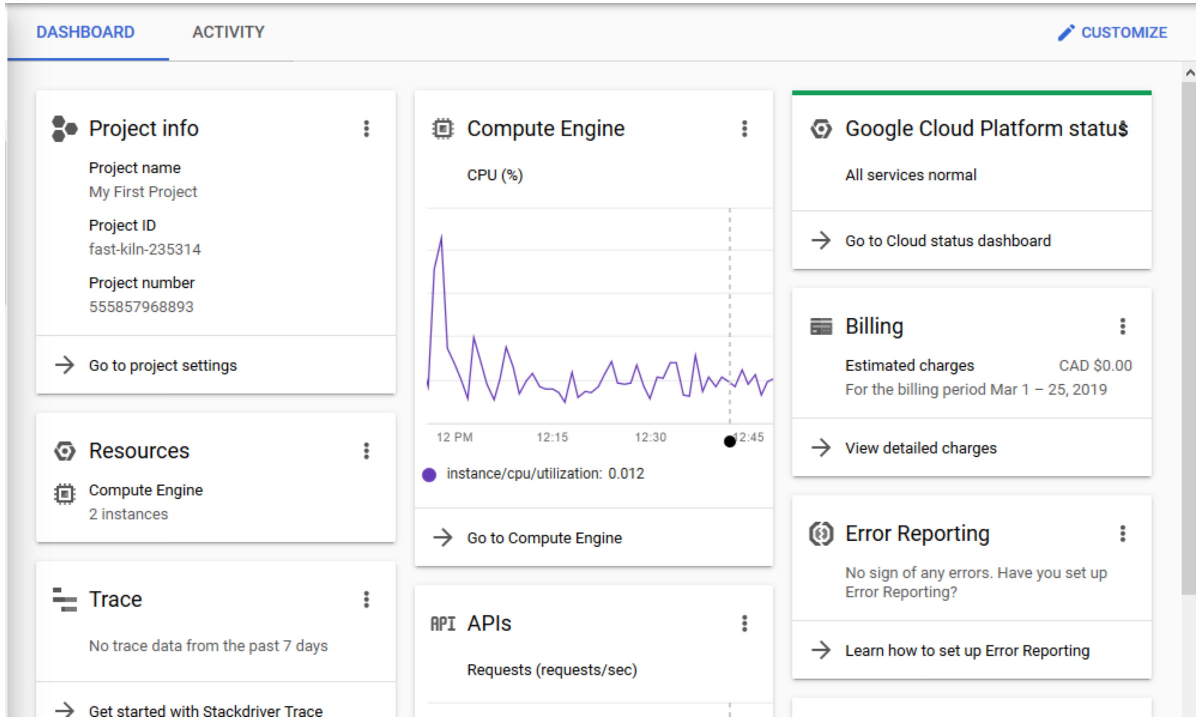
For comparison, we used the leading single-model database systems: Neo4j vs ArangoDB vs MongoDB vs OrientDB .

Test Setup

We used a simple google cloud VM setup and instances google recommends for both relational and non-relational databases.

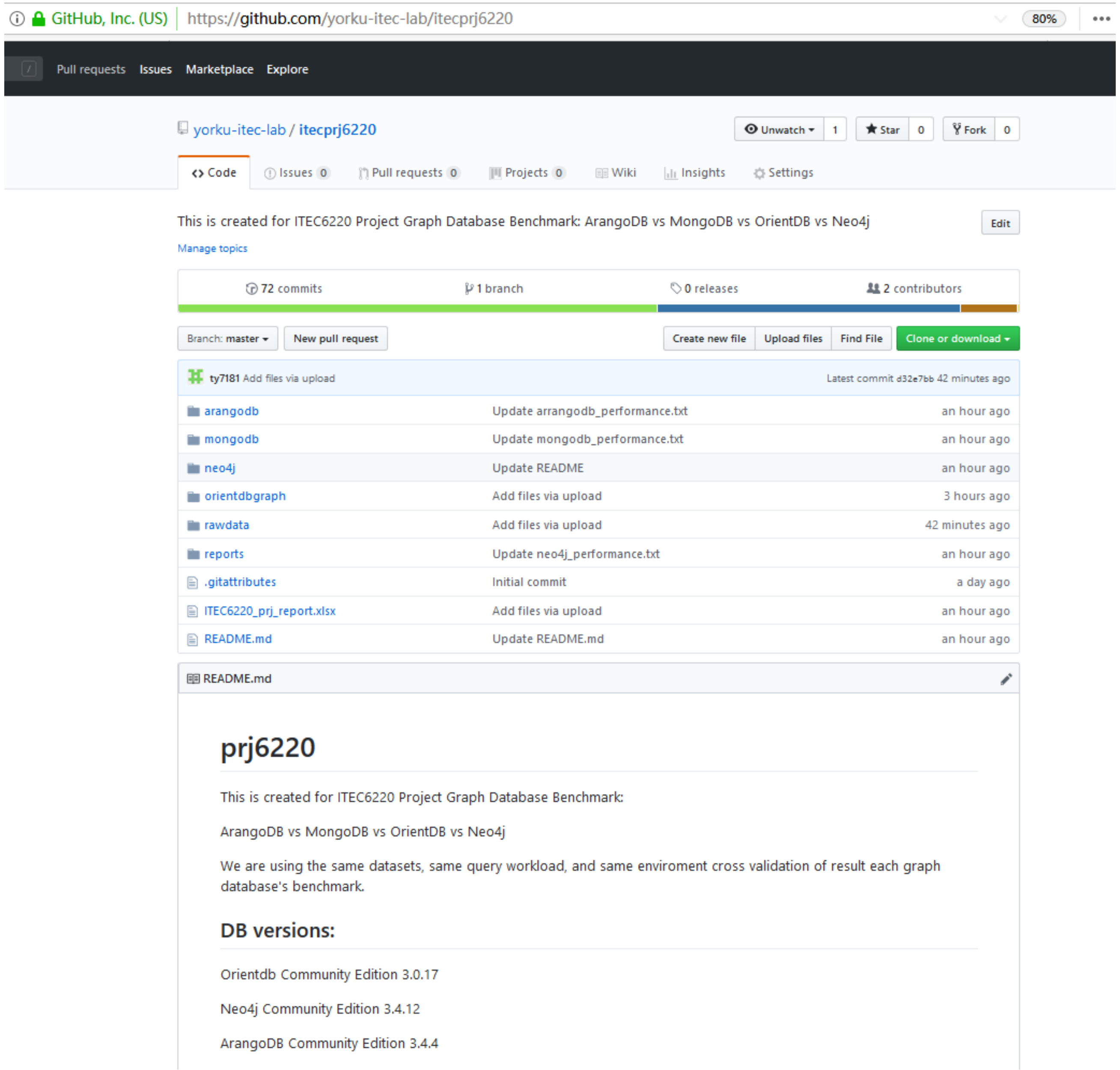
- Machine type

custom (4 vCPU,20 GB memory)
Intel Haswell
Ubuntu 18.04 LTS amd64 bionic image built



Test Setup cont'd

We used a Github repository to host all development code and raw data we got from Stanford University (Stanford Network Analysis Project)



Test Setup cont'd

Dataset statistics	
Nodes	5,881
Edges	35,592
Range of edge weight	-10 to +10
Percentage of positive edges	89%

The dataset is soc-sign-bitcoinotc.csv.gz

Weighted Signed Directed Bitcoin OTC web of trust network

- Each line has one rating, sorted by time, with the following format: SOURCE, TARGET, RATING, TIME

  - SOURCE: node id of source, i.e., rater
  - TARGET: node id of target, i.e., ratee
  - RATING: the source's rating for the target, ranging from -10 to +10 in steps of 1
  - TIME: the time of the rating, measured as seconds since Epoch.

Test Setup cont'd

We used the latest GA versions (as of March 10, 2019) of all database systems and not to include the RC versions. Below are a list of the databases we used for each product:

- Neo4j
- ArangoDB
- MongoDB
- OrientDB
- For this benchmark we used NodeJS 8.9.4 Node.js is an open source server environment, and it allows us to run JavaScript on the server.

Descriptions of Tests

The goal of the benchmark is to measure the performance of each database system when there is no query cache used. To be assured of this, we disabled the query cache for each software that offered one. For our tests we ran the workloads five times, averaging the results. Each test starts with an individual warm-up phase that allows the database systems to load data in memory.

Descriptions of Tests cont'd

The following test cases have been included, as far as the database system was capable of performing the query:

- insert and remove
- simple CRUD, with multiple records retrieving and or updating

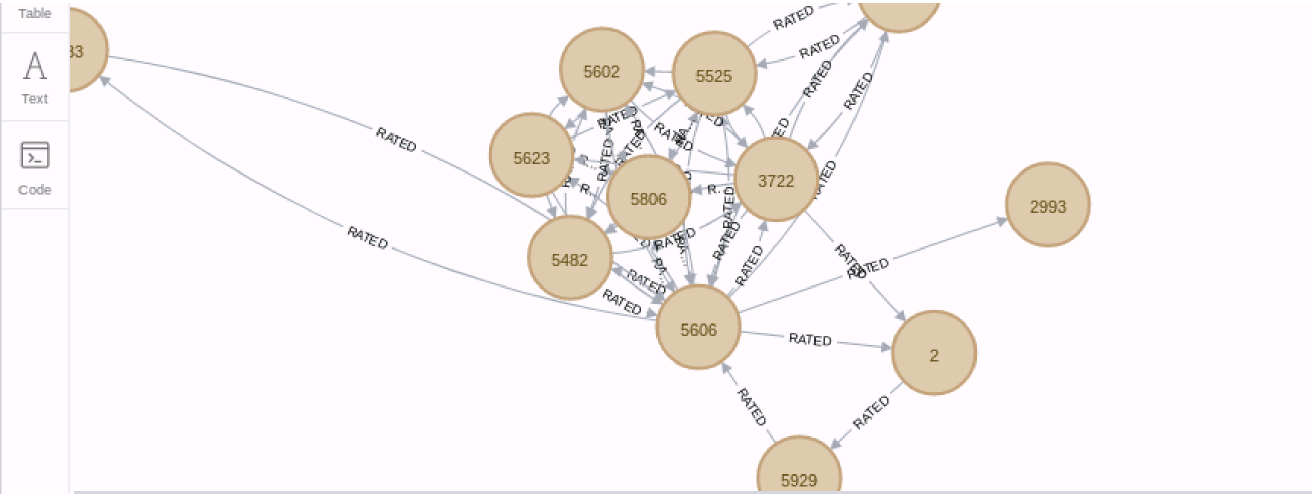
- selection and sort
- Simple CRUD selecting and sorting

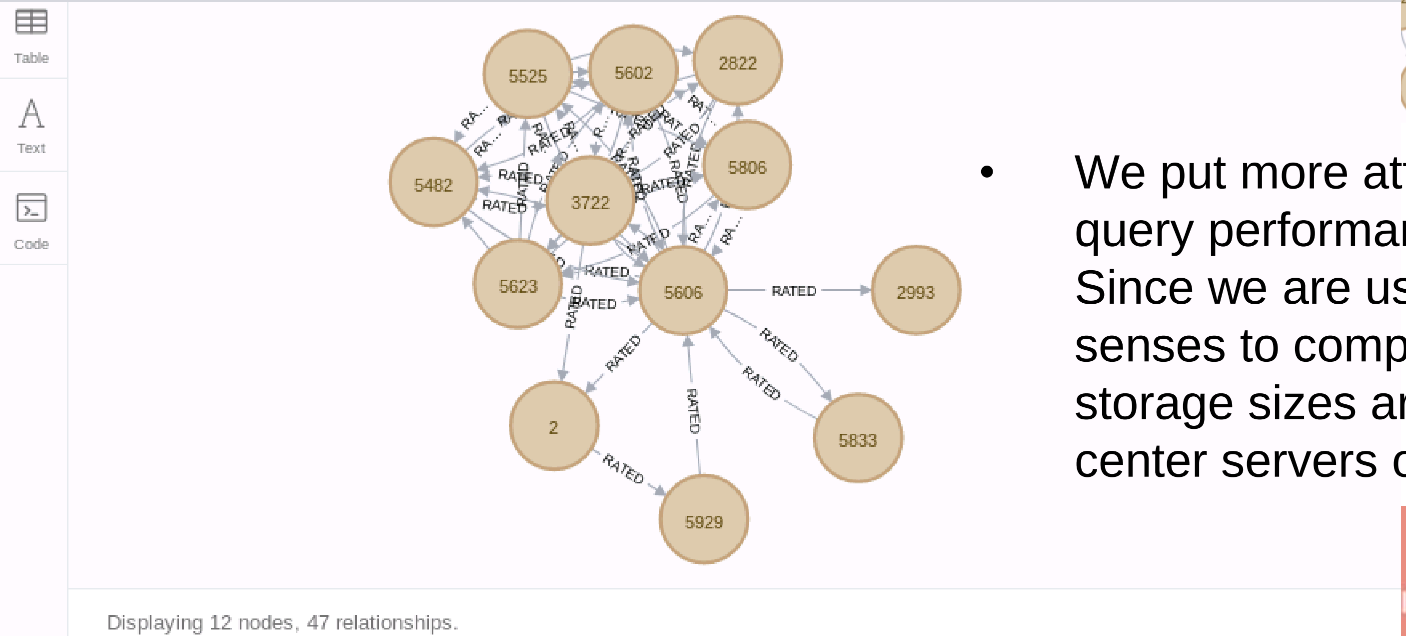
- neighbors
- Finding neighbors nearest: finding (distinct) direct neighbors, returning IDs

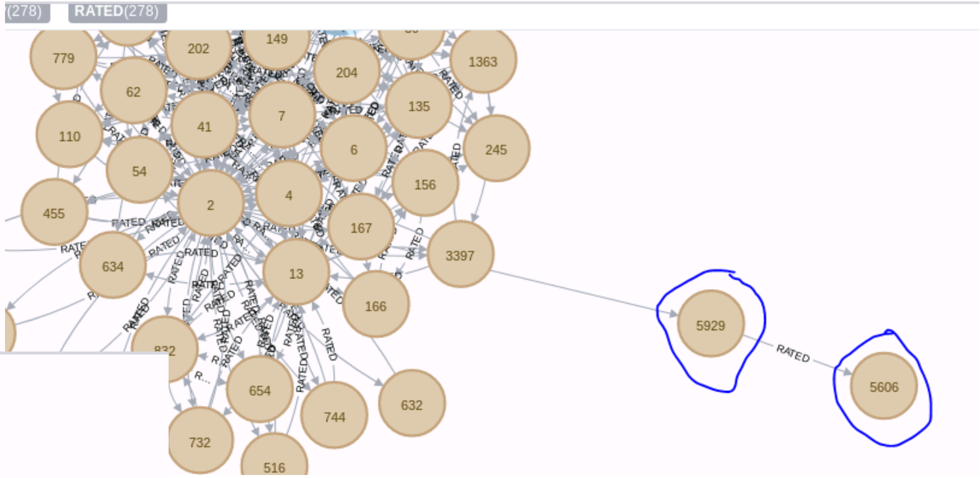
- path finding
- Finding the path length between 2 nodes, Returning all pathes' parts with length 2 and 3, start vertex S and target vertex E:

- Full-text search (on different dataset)

Descriptions of Tests cont'd

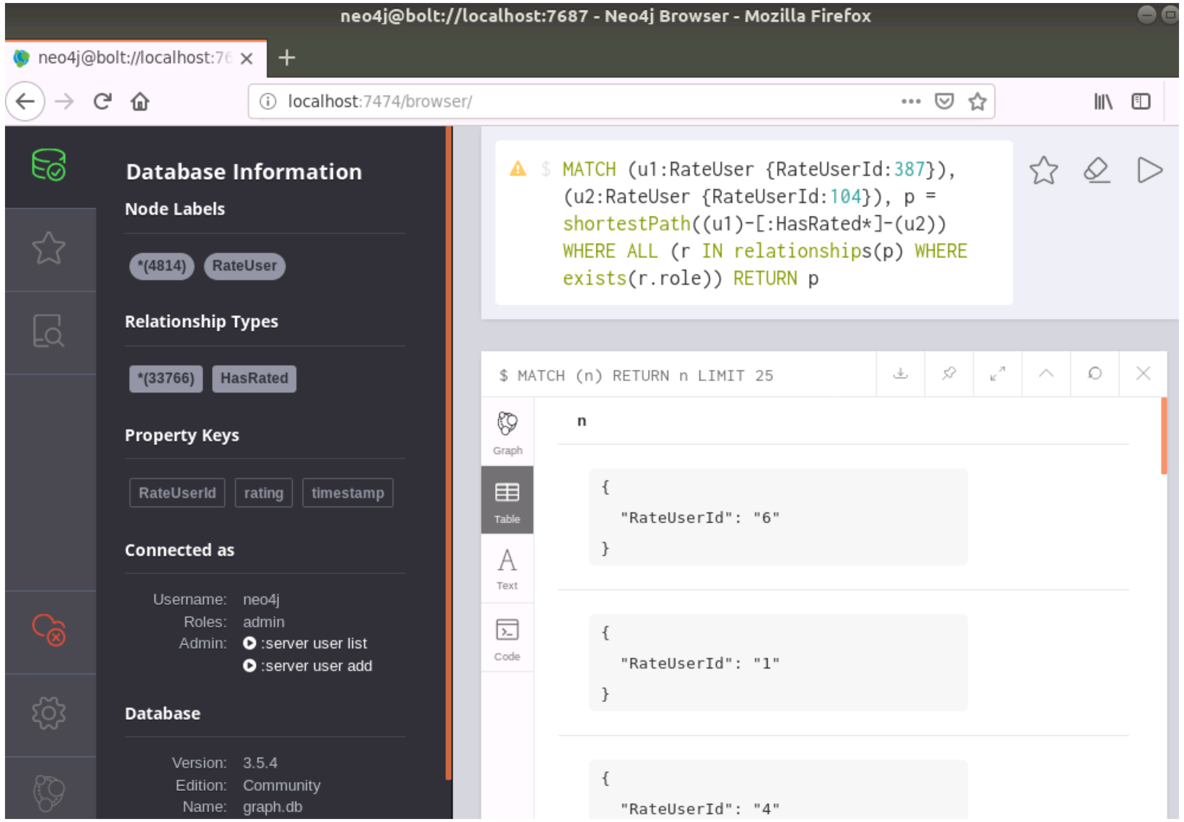






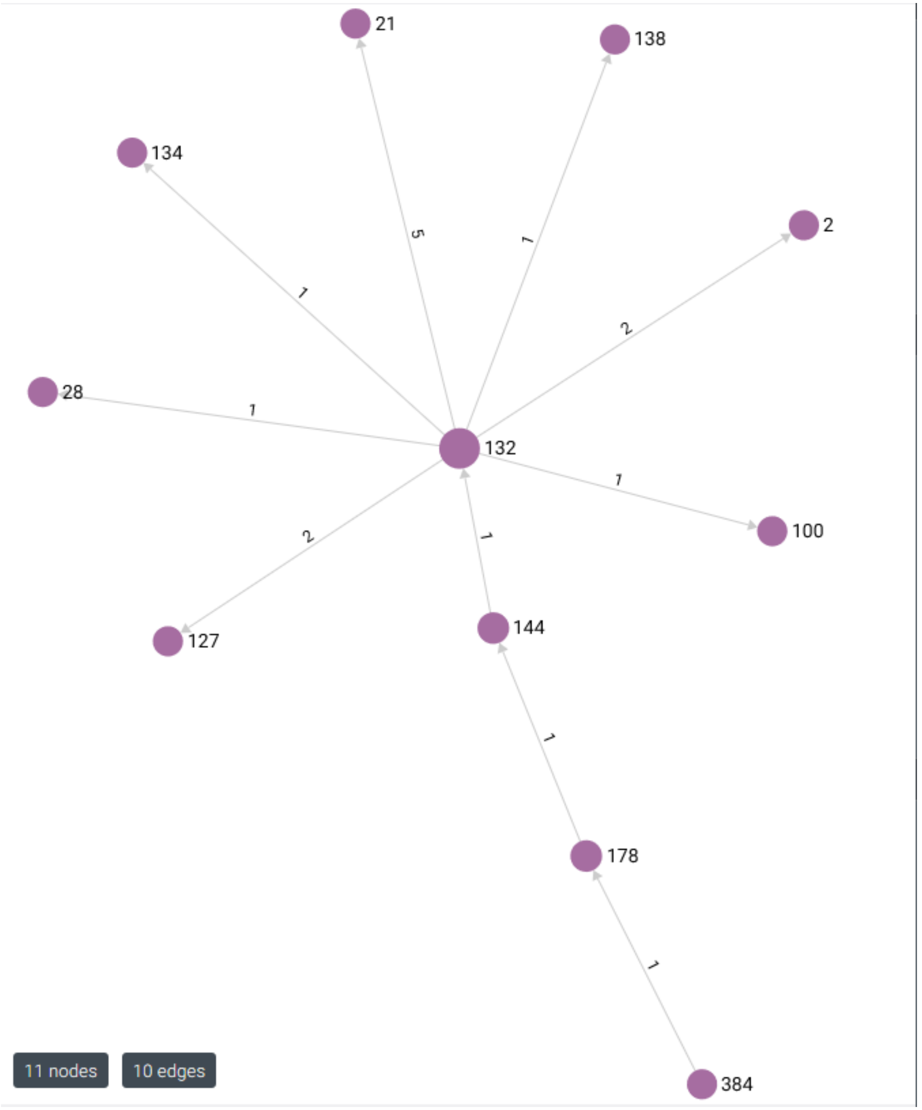
- We put more attentions on the relation analysis and query performance, but not database loading speed. Since we are using free VMs it does not make senses to compare the loading speed due to our storage sizes are very small compare with the data center servers of loaded data

Descriptions of Tests cont'd



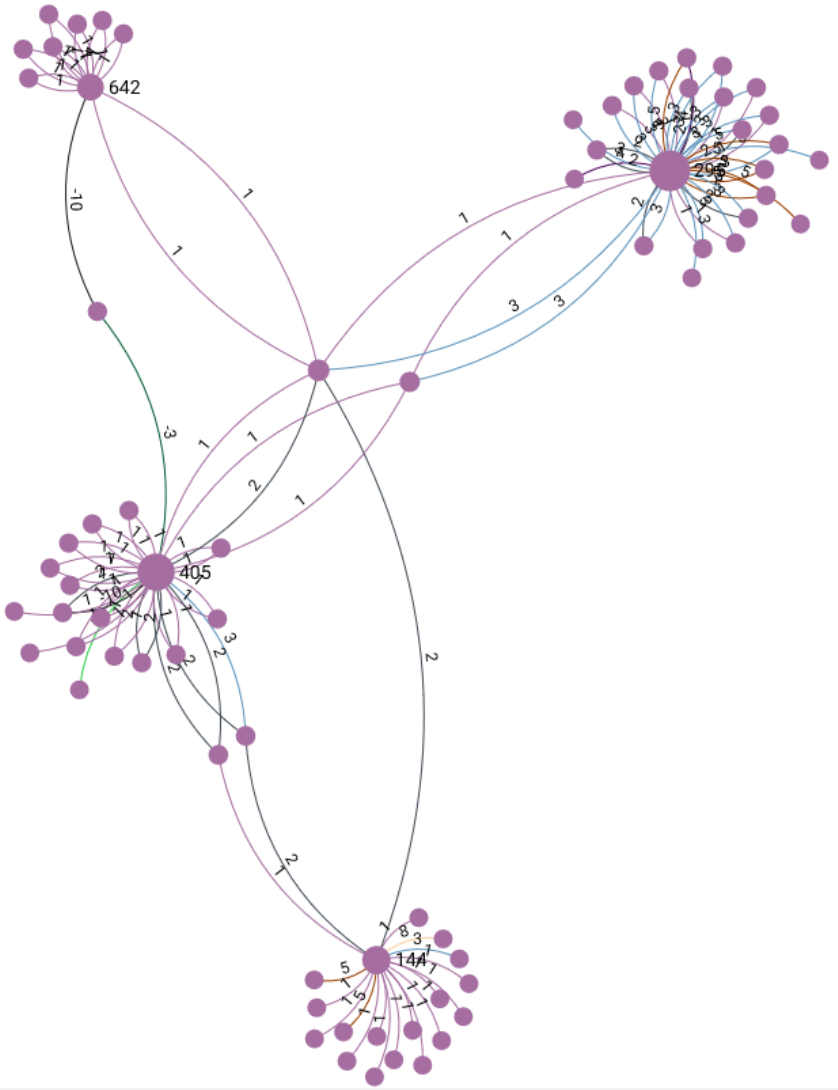
- We think the graph database performance aggregations and result sets is important.
- We measured the average execution times of the proposed shortest path, full-text search and CRUD operations on bit-coin data (Standford Research dataset) by the benchmark with a reasonable number of nodes.
- The graphs were stored as graphs in graph databases
- For most CRUD operations including the graph structure queries in our benchmark, Arango was faster than others.

Descriptions of Tests cont'd



Finding Shortest Paths involves starting from a source node and successively exploring its outgoing edges. We are currently working on extending our benchmark to larger datasets as well as on including more queries.

Descriptions of Tests cont'd



Depth- and Breadth-First Search Algorithms

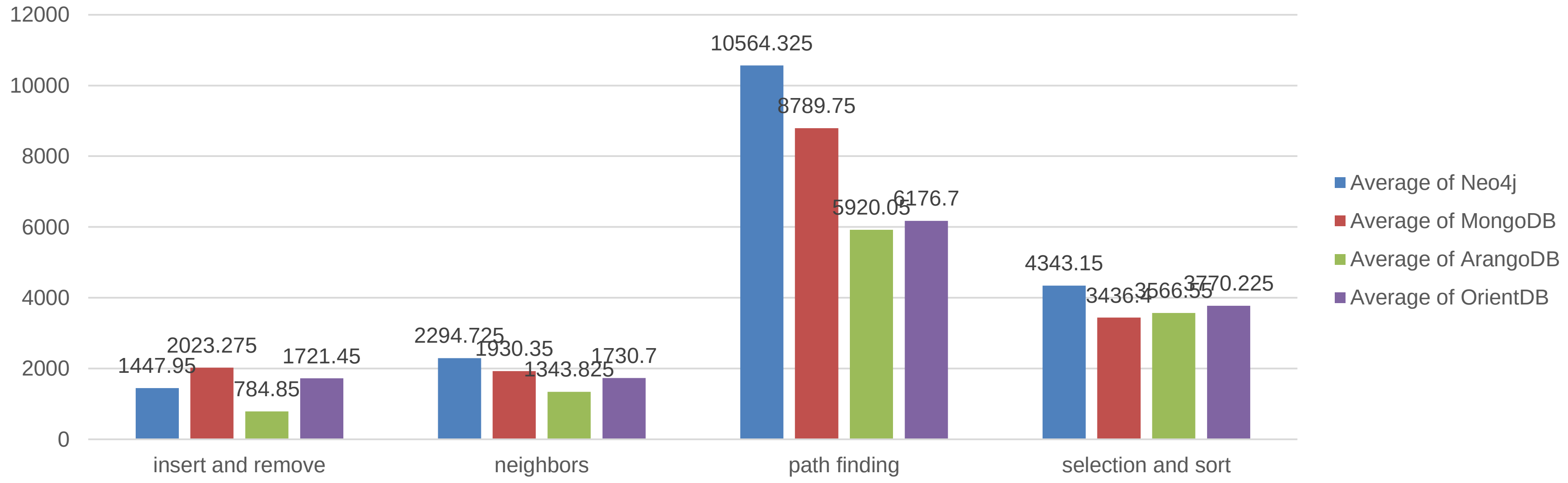
There are two basic types of graph search algorithms: depth-first and breadth-first.

On the contrary, dealing with semantically rich graph databases allows for informed searches, which conduct an early termination of a search if nodes with no compatible outgoing relationships are found. As a result, informed searches also have lower execution times.

As our test results, the ArangoDB performance is the best at this field.

Overall Results

The graph below shows the overall results of our performance benchmark. We noticed the ArangoDB and MongoDB is performance better when request larger amount of IOs, but Neo4j is returning better results when we retrieved small size data.



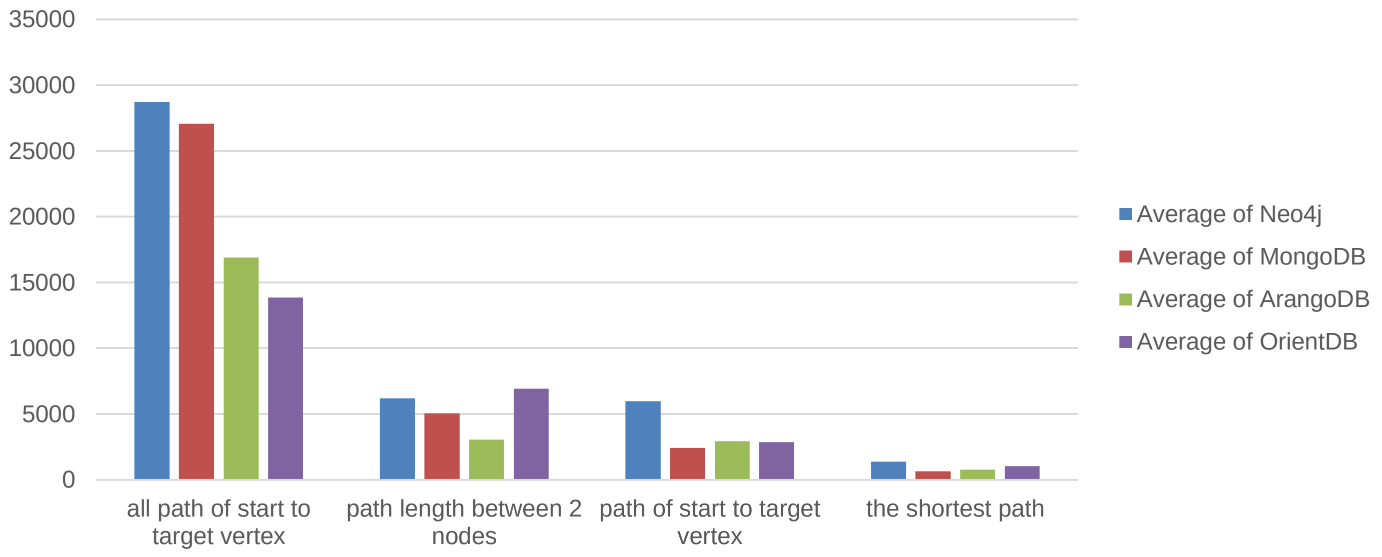
Overall Results cont’d

- In fundamental queries like single-read, single-write, as well as single-write sync Neo4j showed better results in single read/write tests
- These are just the results. To appreciate and understand them, we’ll need look a little deeper into the individual results and focus on the more complex queries like aggregations and graphy functionalities.

Test results for path finding (core performance for graph database)

Group	path finding

Row Labels	Average of Neo4j	Average of MongoDB	Average of ArangoDB	Average of OrientDB
all path of start to target vertex	28717.8	27061.1	16906.3	13866.1
path length between 2 nodes	6189	5040.3	3063.2	6933.1
path of start to target vertex	5982.4	2416.7	2943.8	2864.9
the shortest path	1368.1	640.9	766.9	1042.7
Grand Total	**10564.325**	**8789.75**	**5920.05**	**6176.7**



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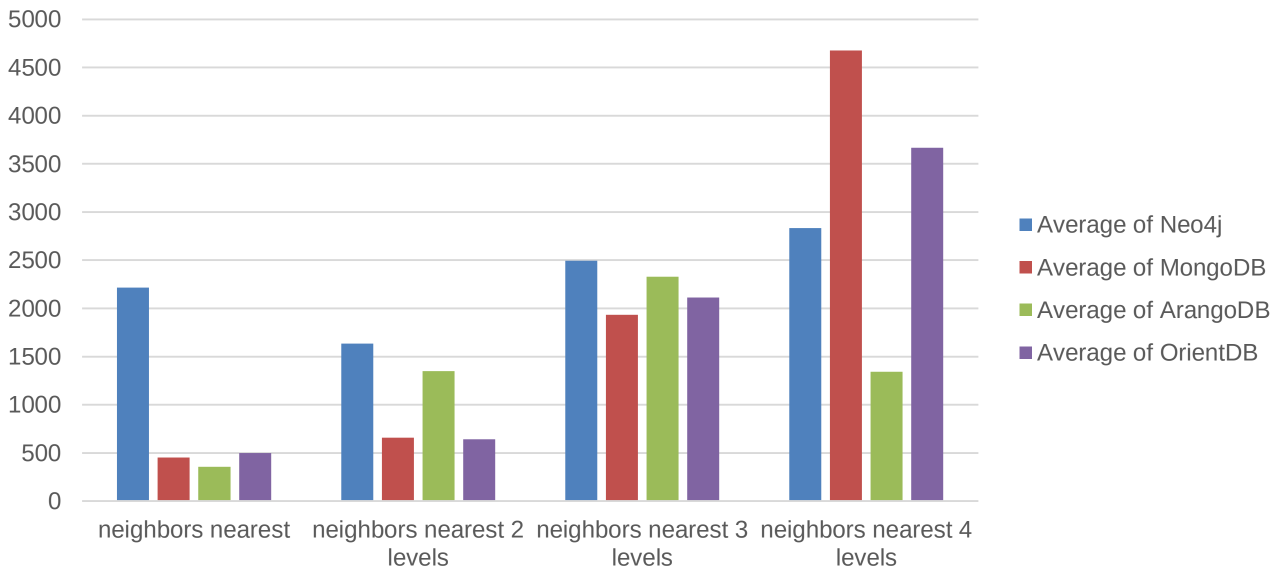
Test results for neighbors finding

Row Labels	Average of Neo4j	Average of MongoDB	Average of ArangoDB	Average of OrientDB
neighbors nearest	2216.5	452.8	357.4	499.9
neighbors nearest 2 levels	1634	658.2	1347.7	642.9
neighbors nearest 3 levels	2494.9	1933.7	2328.9	2113.6
neighbors nearest 4 levels	2833.5	4676.7	1341.3	3666.4
Grand Total	**2294.725**	**1930.35**	**1343.825**	**1730.7**



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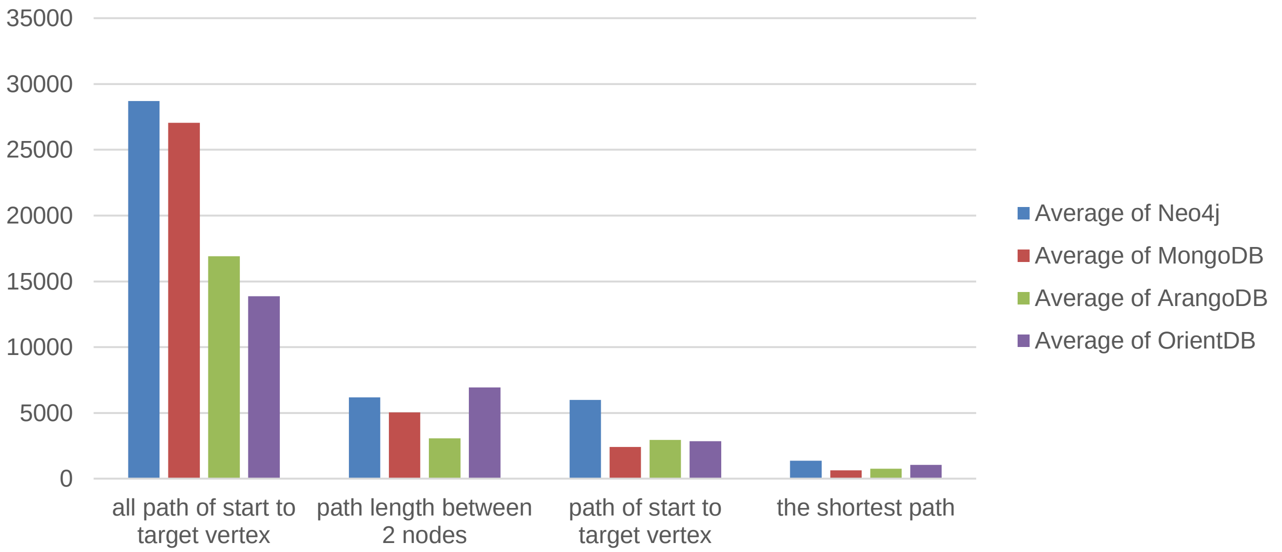
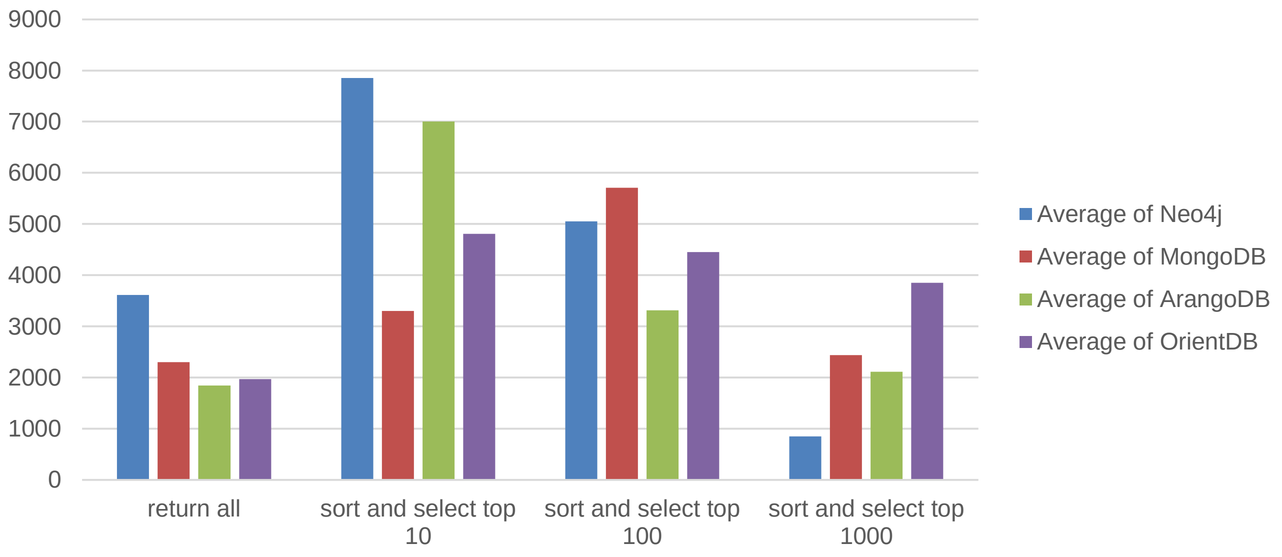


Test results for selections (simple and complex)

Row Labels	Average of Neo4j	Average of MongoDB	Average of ArangoDB	Average of OrientDB
return all	3615.4	2297.4	1841.4	1968.7
sort and select top 10	7855.4	3302	7000.6	4809.5
sort and select top 100	5050.5	5708.5	3314.8	4451.7
sort and select top 1000	851.3	2437.7	2109.4	3851
Grand Total	**4343.15**	**3436.4**	**3566.55**	**3770.225**



Conclusion

- When doing benchmark tests that different hardware can produce different results.

- The performance needs may vary and the requirements may differ.

- In this benchmark we could show, that ArangoDB and MongoDB can compete with the leading single-model database systems on their home turf.

- In conclusion, the excellent performance of a ArangoDB is a key advantage of others

Extra Exam - Text search – MongoDB vs. ArangoDB

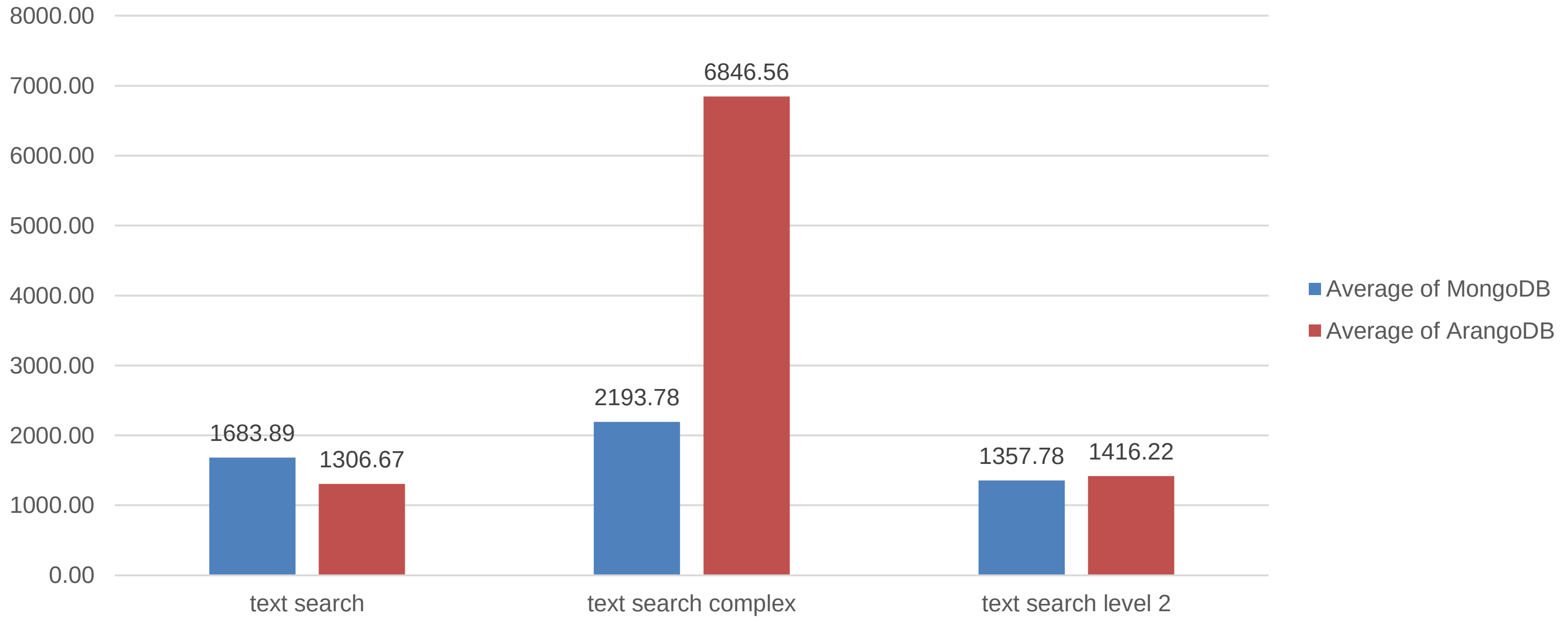
Due to the data complexity, we only completed the text search performance comparing between MongoDB and ArangoDB

We are using Infrastructure Canada Projects data

Index and search text by using Infrastructure Canada Projects Data. The publisher - Current Organization Name: Infrastructure Canada, This dataset contains a list of infrastructure projects across Canada that have been approved by Infrastructure Canada. The project information listed is based on current information.

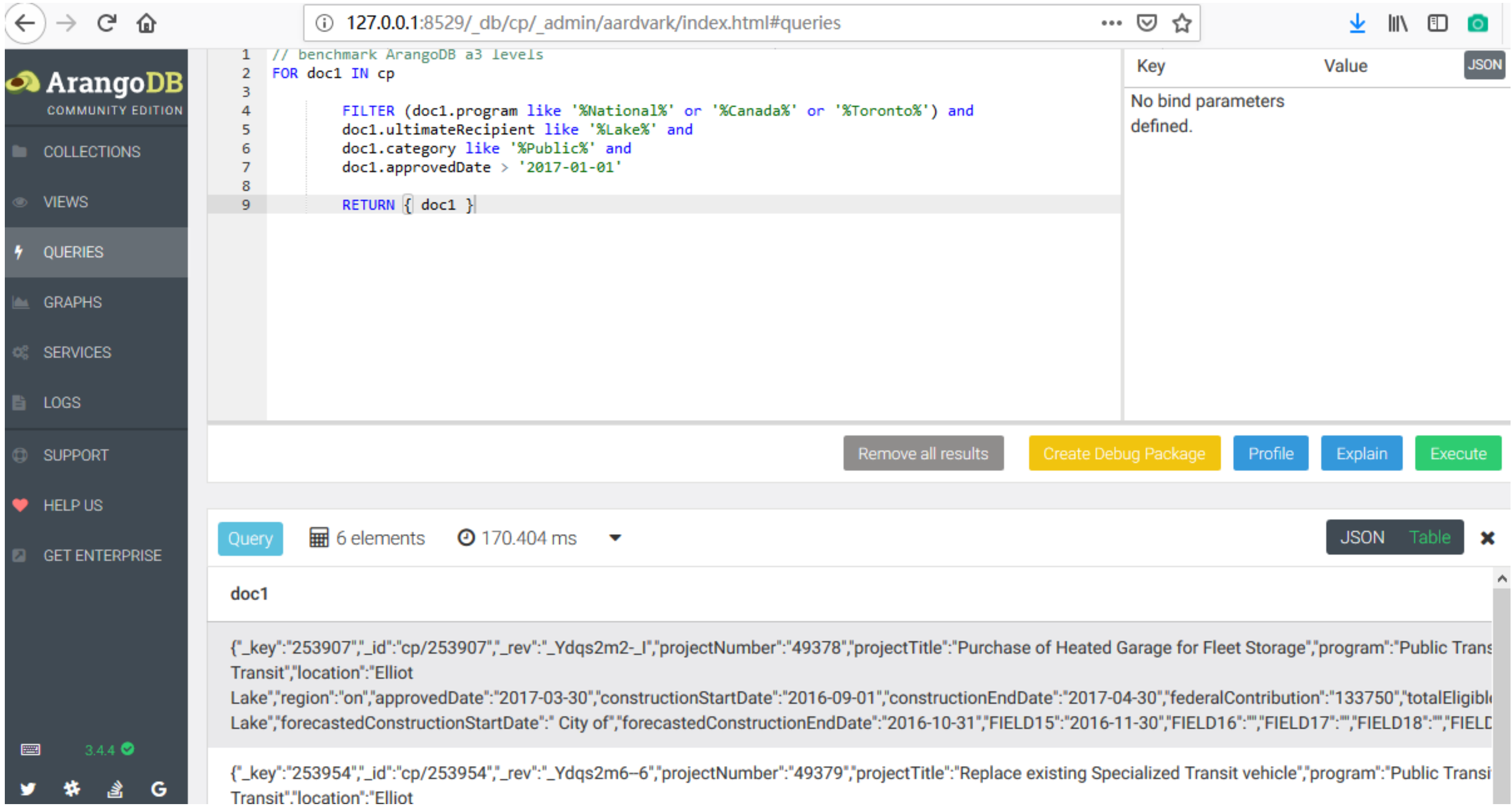
Text search – MongoDB vs. ArangoDB cont'd

As the results show, the MongoDB text search performance much better when have complex conditions, but ArangoDB performance better when search simple key words.



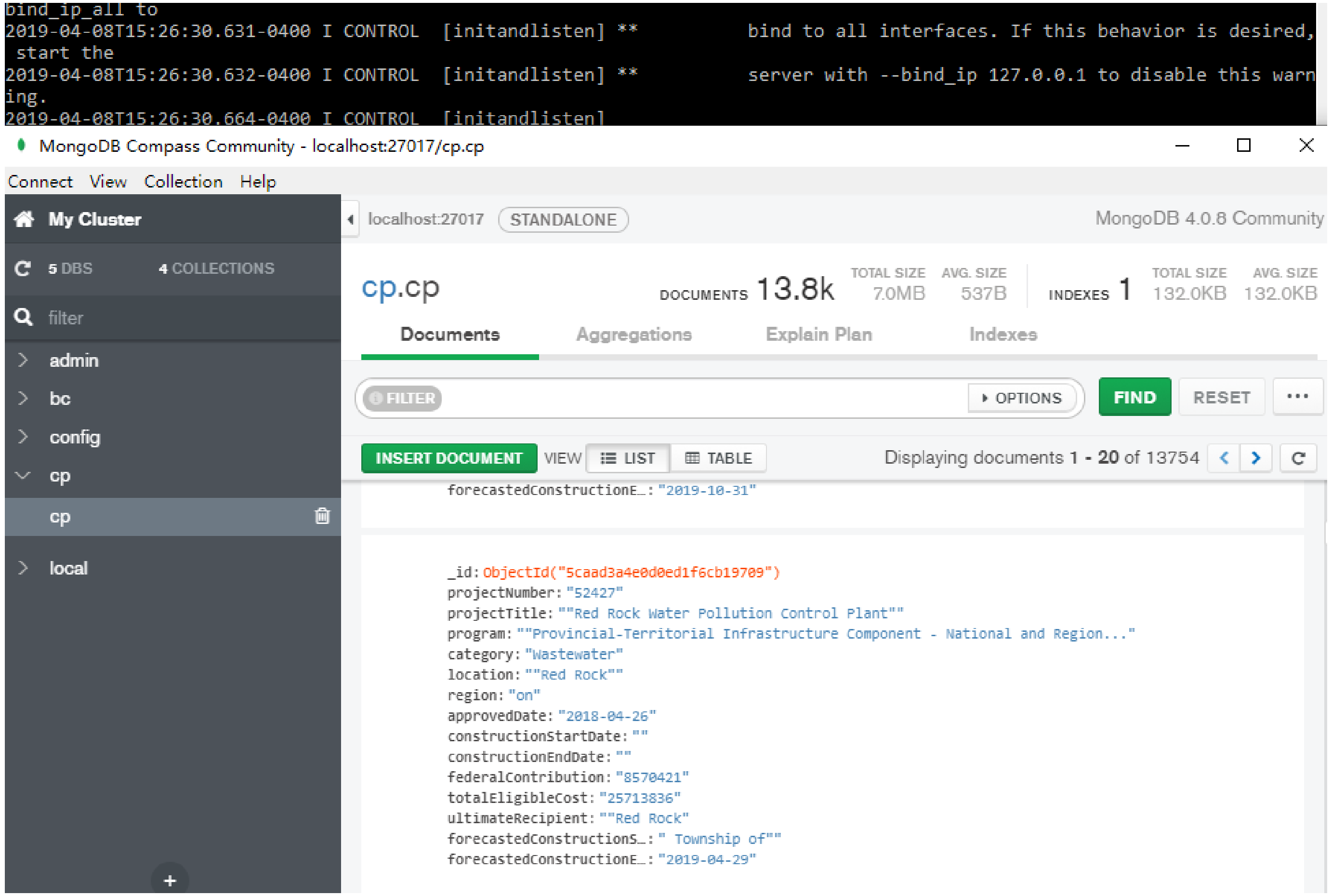
Text search – MongoDB vs. ArangoDB cont'd

Optimizing the storage of facts that refer to the same entity is an important aspect of the graph database enabling fast queries and inference.



Text search – MongoDB vs. ArangoDB cont’d

It allows us to develop hybrid queries that include semantic facts and full-text search within unstructured data.



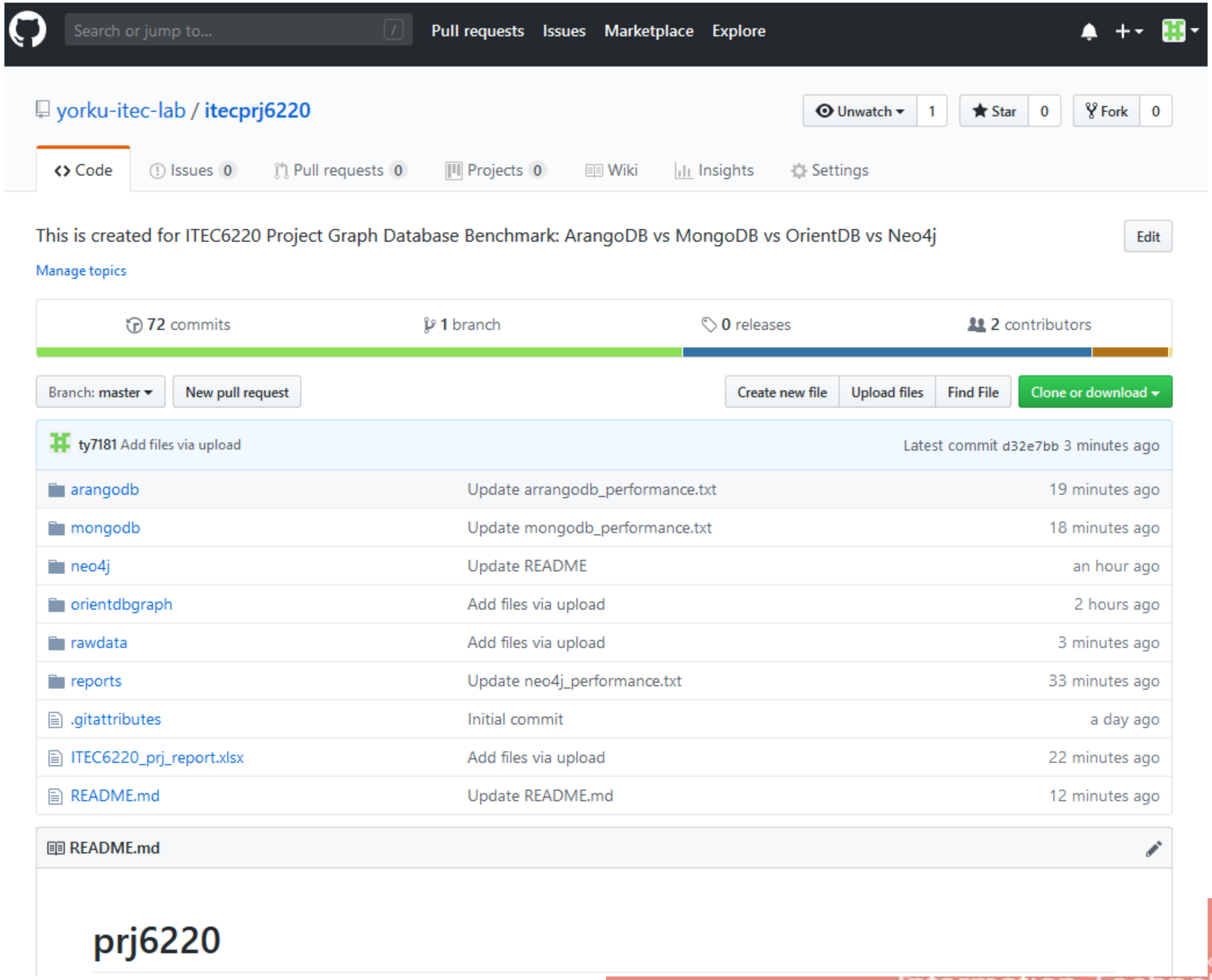
Future work

- For this graph database performance benchmark, we used the same dataset and the same hardware to test each database system.

- In the future, need to check or understand better the results under different systems for different set of the data, the equipment, and the software.

- We made sure for each experiment that the database had a chance to load all relevant data into RAM. Therefore, we increased cache sizes where relevant and used full collection scans as a warm-up procedure.

Appendix - Test results - https://github.com/yorku-itec-lab/itecprj6220



Appendix - Test results cont'd

yorku-itec-lab / itecprj6220

Unwatch 1 | Star 0 | Fork 0

Code | Issues 0 | Pull requests 0 | Projects 0 | Wiki | Insights | Settings

Branch: master | itecprj6220 / reports / neo4j_performance.txt | Find file | Copy path

ty7181 Update neo4j_performance.txt 6832f9d 2 hours ago

2 contributors

162 lines (161 sloc) | 5.08 KB | Raw | Blame | History

```
Import Execution took: 399466 ms
Query 1 Execution took: 962 ms
Query 2 Execution took: 1165 ms
Query 3 Execution took: 1434 ms
Query 4 Execution took: 2897 ms
Query 5 Execution took: 2277 ms
Query 6 Execution took: 4559 ms
Query 7 Execution took: 2275 ms
Query 8 Execution took: 2420 ms
Query 9 Execution took: 758 ms
Query 10 Execution took: 4068 ms
Query 11 Execution took: 759 ms
Query 12 Execution took: 1217 ms
Query 13 Execution took: 2996 ms
Query 14 Execution took: 3505 ms
Query 15 Execution took: 16010 ms
Query 16 Execution took: 1005 ms
Query 1 Execution took: 1142 ms
Query 2 Execution took: 1505 ms
Query 3 Execution took: 1460 ms
Query 4 Execution took: 3965 ms
Query 5 Execution took: 2864 ms
Query 6 Execution took: 6095 ms
Query 7 Execution took: 3143 ms
Query 8 Execution took: 1773 ms
Query 9 Execution took: 1065 ms
Query 10 Execution took: 3452 ms
Query 11 Execution took: 774 ms
Query 12 Execution took: 1037 ms
Query 13 Execution took: 3915 ms
Query 14 Execution took: 4397 ms
Query 15 Execution took: 18426 ms
Query 16 Execution took: 1081 ms
Query 1 Execution took: 1581 ms
Query 2 Execution took: 1168 ms
Query 3 Execution took: 1901 ms
Query 4 Execution took: 3501 ms
Query 5 Execution took: 3506 ms
Query 6 Execution took: 5505 ms
```

yorku-itec-lab / itecprj6220

Unwatch 1 | Star 0 | Fork 0

Code | Issues 0 | Pull requests 0 | Projects 0 | Wiki | Insights | Settings

Branch: master | itecprj6220 / reports / neo4j_report.txt | Find file | Copy path

johnql Add files via upload 3caae34 8 hours ago

1 contributor

238 lines (236 sloc) | 28.8 KB | Raw | Blame | History

```
neo4j testing started...\n
neo4j query 1 report...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j testing started...\n
neo4j query 1 report...\n
u1, u2
(:RateUser {RateUserId: "5929"}), (:RateUser {RateUserId: "5606"})
neo4j query 1 report...\n
u1, u2
(:RateUser {RateUserId: "5929"}), (:RateUser {RateUserId: "5606"})
neo4j query 2 report...\n

neo4j query 3 report...\n
u1, u2, u3, u4
(:RateUser {RateUserId: "5929"}), (:RateUser {RateUserId: "5606"}), (:RateUser {RateUserId: "5806"}), (:RateUser {RateUserId: "5606"})
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Thank you