In [ ]:
```
import os
import importlib
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from testing import TestBuilder
from database import connection
from controllers import user, poll
from testcontainers.mongodb import MongoDbContainer
from testcontainers.postgres import PostgresContainer
```

In [ ]:
```
# Create a plot to compare 2 sets of data.

def create_plot_comparison(labels, a_data, b_data, a_label, b_label, x_label, y_label, title):
    X_axis = np.arange(len(labels))

    plt.bar_label(plt.bar(X_axis - 0.2, a_data, 0.4, label = a_label), padding=3)
    plt.bar_label(plt.bar(X_axis + 0.2, b_data, 0.4, label = b_label), padding=3)

    plt.xticks(X_axis, labels)
    plt.xlabel(x_label)
    plt.ylabel(y_label)
    plt.title(title)
    plt.legend()
    plt.show()
```

Tests running on local docker containerized tests

In [ ]:
```
importlib.reload(connection)

# Run tests on MongoDB in container.

with MongoDbContainer("mongo:latest") as mongo:
    con = connection.ContainerMongoConnection(mongo)
    tests = TestBuilder(con, con, user.UserControllerMongo, poll.PollControllerMongo)
    mongo_test_results = tests.run_all(1000, 1000)
```

```
Pulling image mongo:latest
Container started: 969f52d6ddf7
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
```

In [ ]:
```python
importlib.reload(connection)

# Run tests on MongoDB using reference in container.

with MongoDbContainer("mongo:latest") as mongo:
    con = connection.ContainerMongoConnection(mongo)
    tests = TestBuilder(con, con, user.UserControllerMongo, poll.PollControllerMongoReferenced)
    mongo_ref_test_results = tests.run_all(1000, 1000)
```

```
Pulling image mongo:latest
Container started: e5635a98d276
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
```

In [ ]:
```python
importlib.reload(connection)

# Run tests on MongoDB using aggregate in container.

with MongoDbContainer("mongo:latest") as mongo:
    con = connection.ContainerMongoConnection(mongo)
    tests = TestBuilder(con, con, user.UserControllerMongoAggregate, poll.PollControllerMongo)
    mongo_aggregate_test_results = tests.run_all(1000, 1000)
```

```
Pulling image mongo:latest
Container started: 072cffbd07b4
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
```

In [ ]:
```
importlib.reload(connection)

# Run tests on MongoDB using an index on the Polls collection.

with MongoDbContainer("mongo:latest") as mongo:
    con = connection.ContainerMongoConnection(mongo)
    con.db["users"].create_index("user_index", unique=True)
    tests = TestBuilder(con, con, user.UserControllerMongo, poll.PollControllerMongo)
    mongo_index_test_results = tests.run_all(1000, 1000)
```

```
Pulling image mongo:latest
Container started: 8d3d32ae2672
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
```

In [ ]:
```
importlib.reload(connection)

# Run tests on Postgres in container.

with PostgresContainer("postgres:latest") as postgres:
    con = connection.ContainerSQLConnection(postgres)
    tests = TestBuilder(con, con, user.UserControllerSql, poll.PollControllerSql)
    psql_test_results = tests.run_all(1000, 1000)
```

```
Pulling image postgres:latest
Container started: 3a4bd4f6a7f4
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
Waiting to be ready...
```

Tests running on MongoDB Atlas connection

In [ ]:
```
importlib.reload(connection)
```

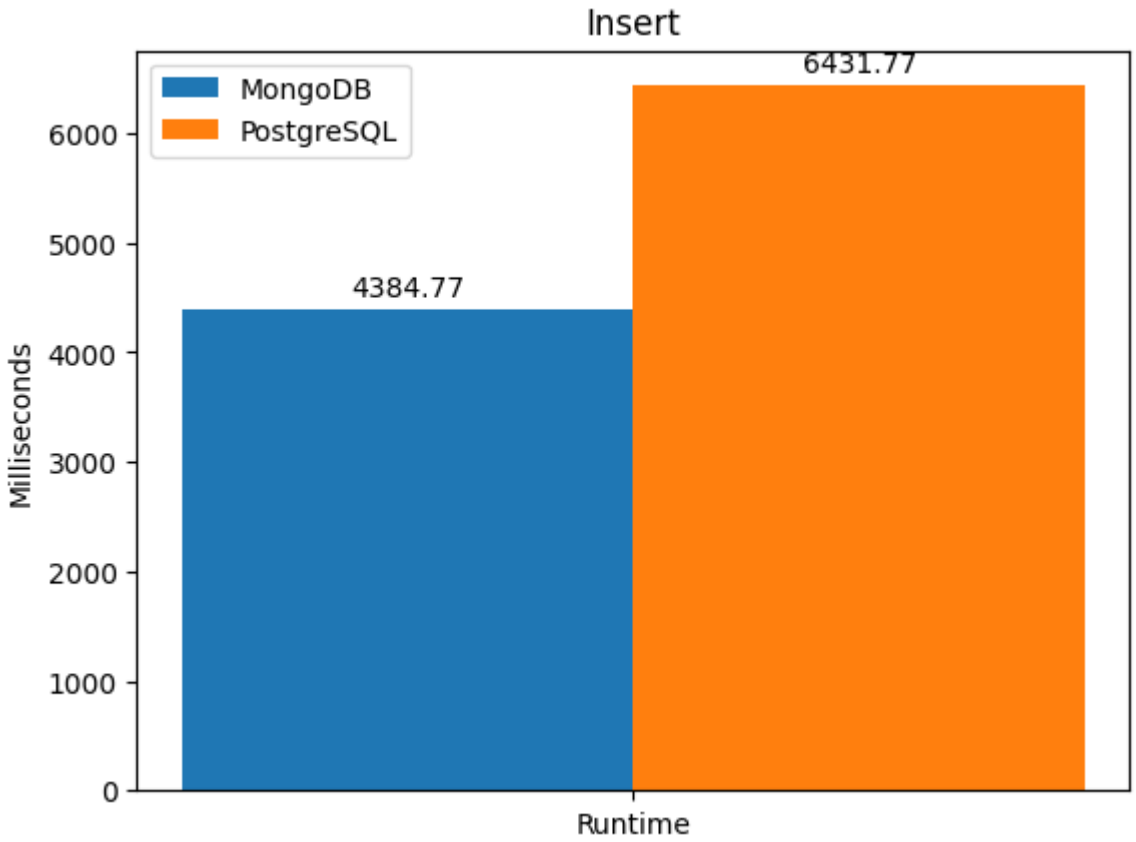
```
con = connection.MongoConnection("connection str", "test")
tests = TestBuilder(con, con, user.UserControllerMongo, poll.PollControllerMongo)
mongo_atlas_test_results = tests.run_all(100, 100)
con.client.close()
```

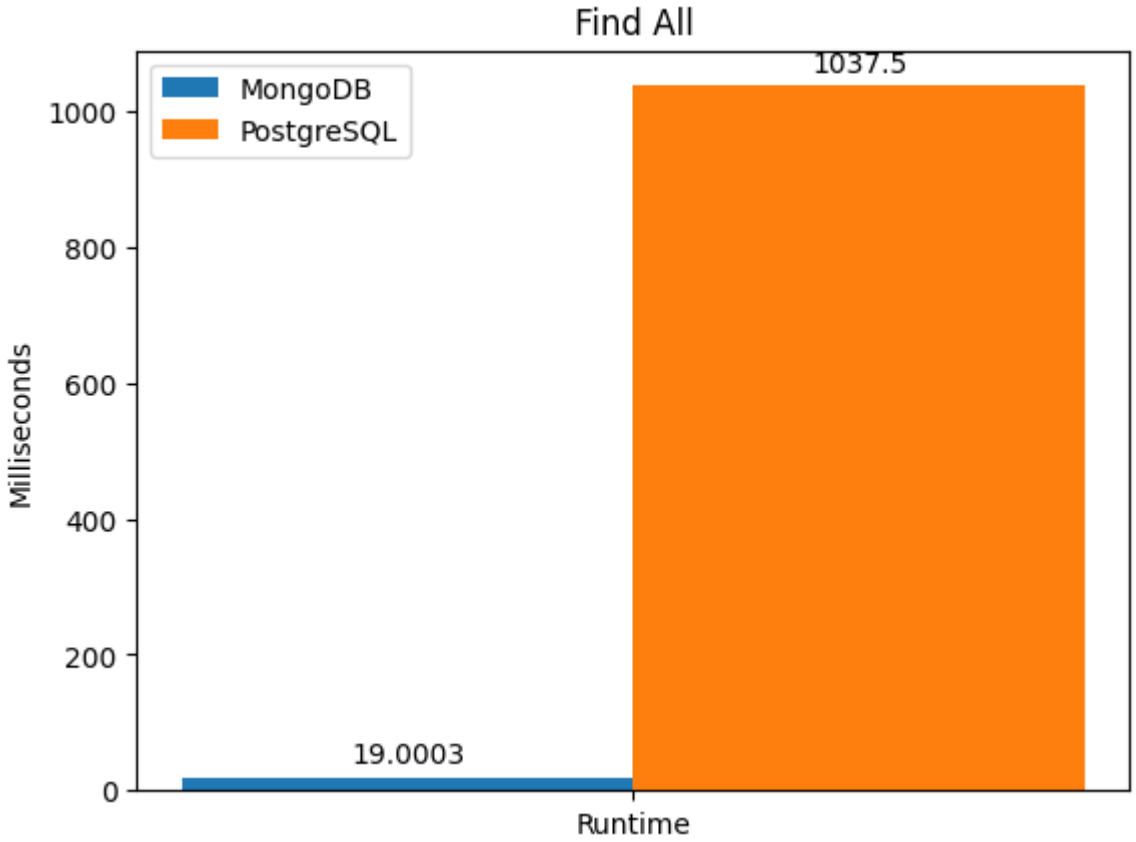
Tests running on PostgreSQL Elephant connection

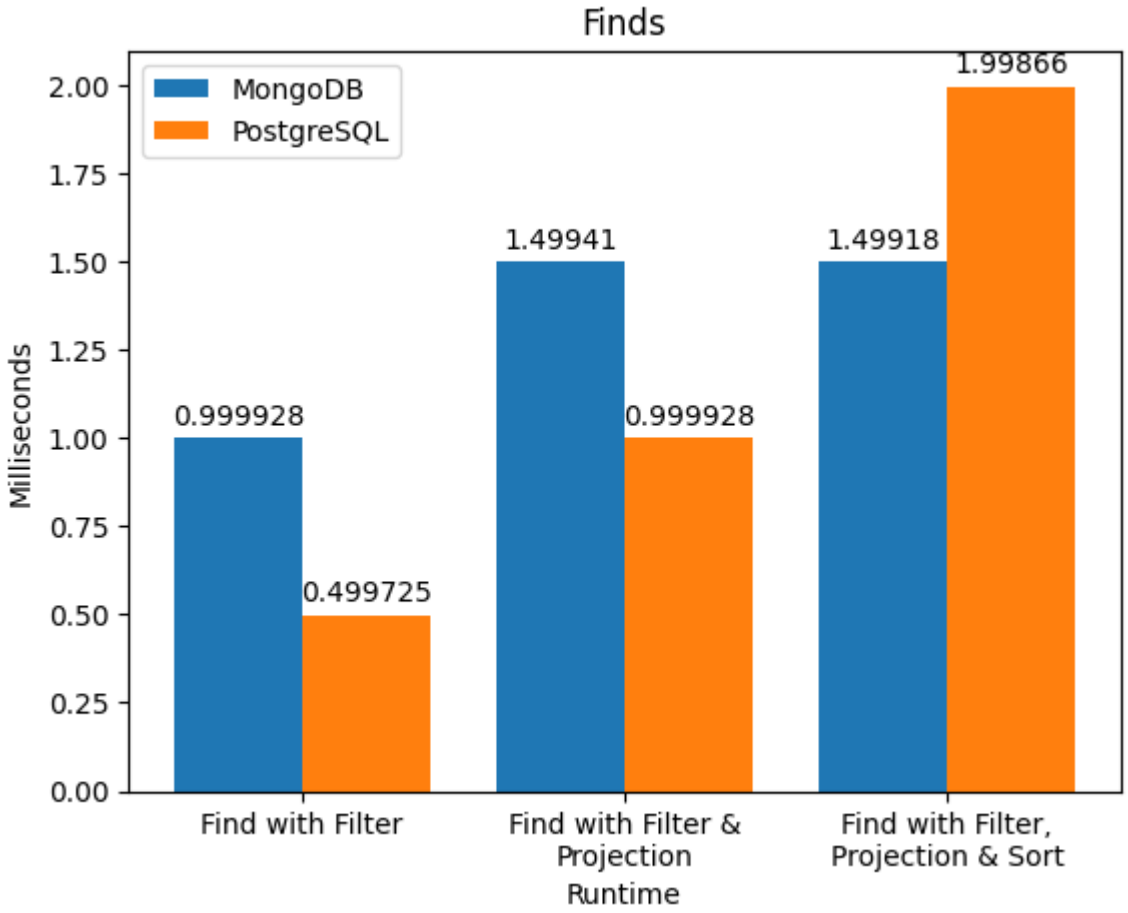
In [ ]:
```
importlib.reload(connection)

con = connection.SQLConnection("horton.db.elephantsql.com", "db_name", "user", "pass")
tests = TestBuilder(con, con, user.UserControllerSql, poll.PollControllerSql)
psql_cloud_test_results = tests.run_all(100, 100)
```

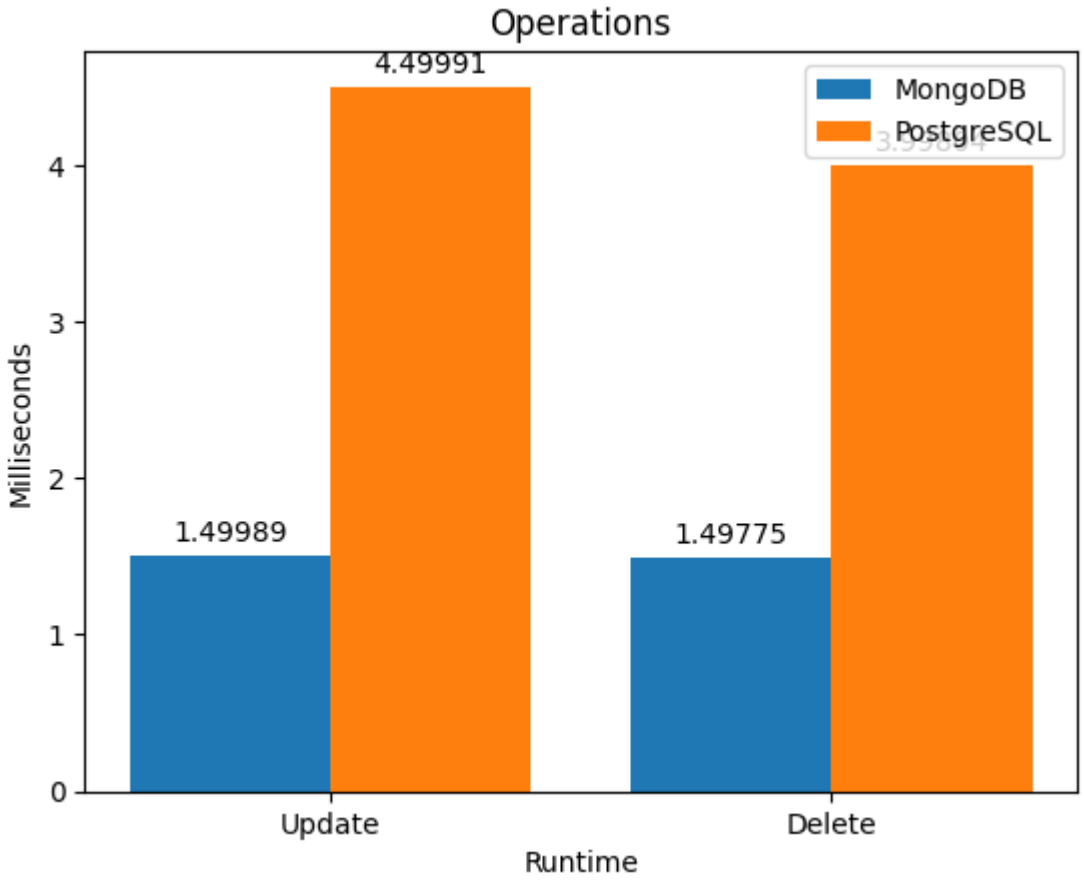
Comparison of various operations between MongoDB and PostgreSQL on the local machine

In [ ]:
```
create_plot_comparison(["Runtime"], [mongo_test_results["bulk_insertion"]*1000], [psql_test_results["bulk_insertion"]*1000], "

create_plot_comparison(["Runtime"], [mongo_test_results["find_all"]*1000], [psql_test_results["find_all"]*1000], "MongoDB", "P

create_plot_comparison(["Find with Filter", "Find with Filter &\nProjection", "Find with Filter,\nProjection & Sort"], [mongo_

create_plot_comparison(["Update", "Delete"], [mongo_test_results["update"]*1000, mongo_test_results["delete"]*1000], [psql_tes
```


Insert
MongoDB
PostgreSQL
6431.77
4384.77
Milliseconds
0
1000
2000
3000
4000
5000
6000
Runtime


Find All
MongoDB
PostgreSQL
1037.5
19.0003
Milliseconds
0
200
400
600
800
1000
Runtime

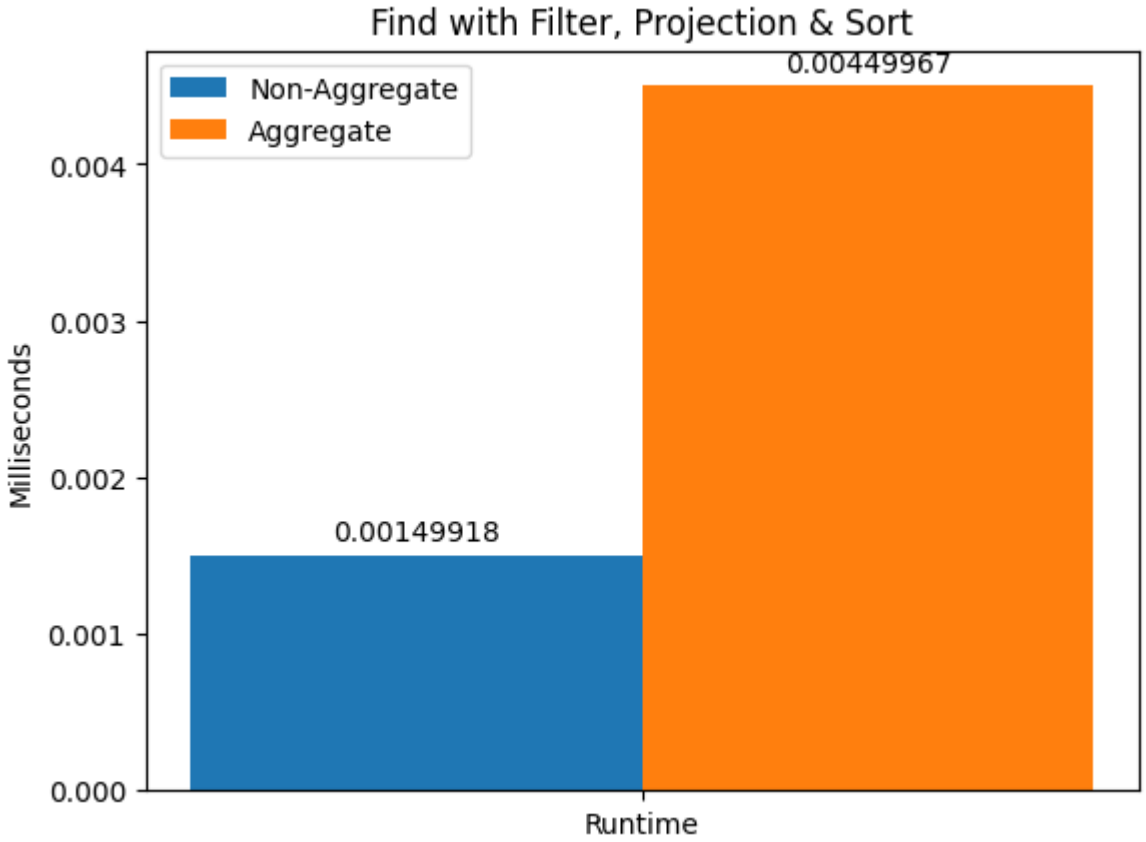

Finds
MongoDB
PostgreSQL
Milliseconds
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.999928
0.499725
1.49941
0.999928
1.49918
1.99866
Find with Filter
Find with Filter & Projection
Find with Filter, Projection & Sort
Runtime



The next plot compares the usage of a search operation using MongoDB aggregate vs non-aggregates

Non-aggregated operations seem to be executed in half the time.

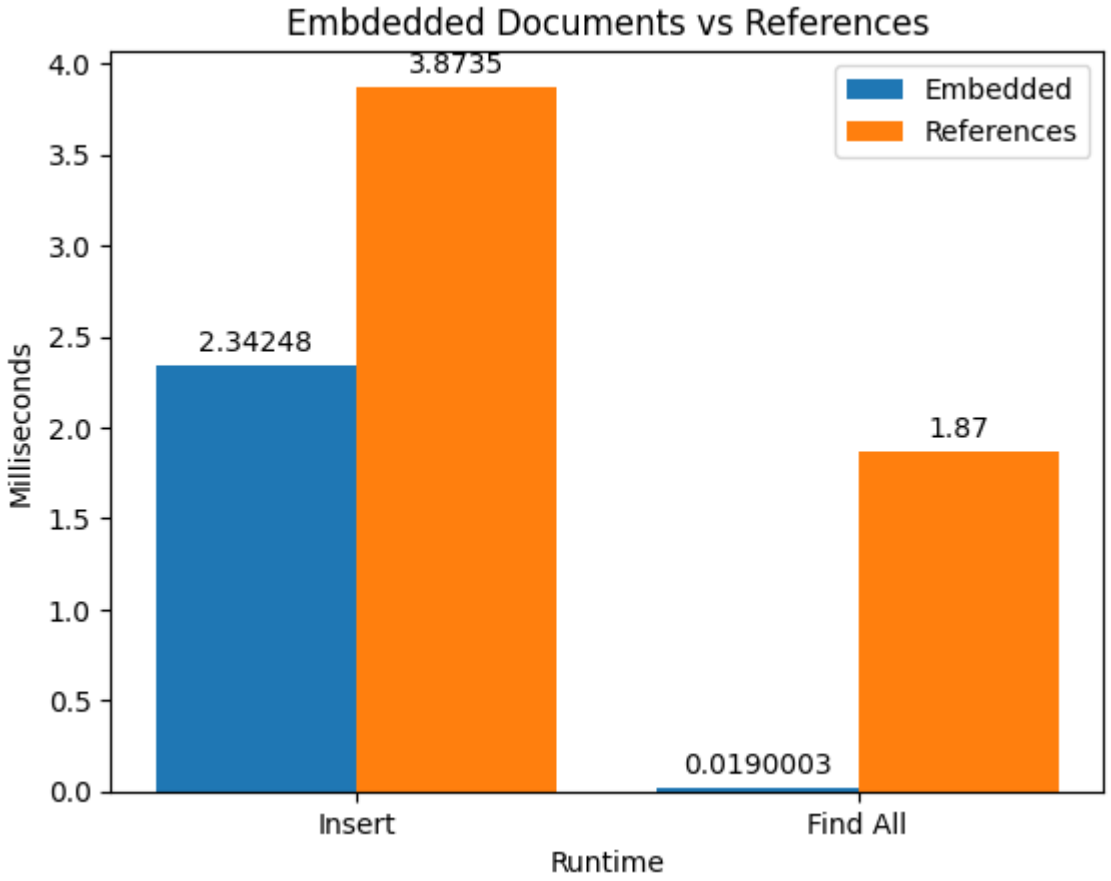
In [ ]:
```
create_plot_comparison(["Runtime"], [mongo_test_results["filter_project_sort"]], [mongo_aggregate_test_results["filter_project
```



The next plot compares the usage of a model based on embedded doucments compared to references

Embedded documents seem to make a significant difference when it comes runtime probably because they are built-in while references need multiple finds to be executed.

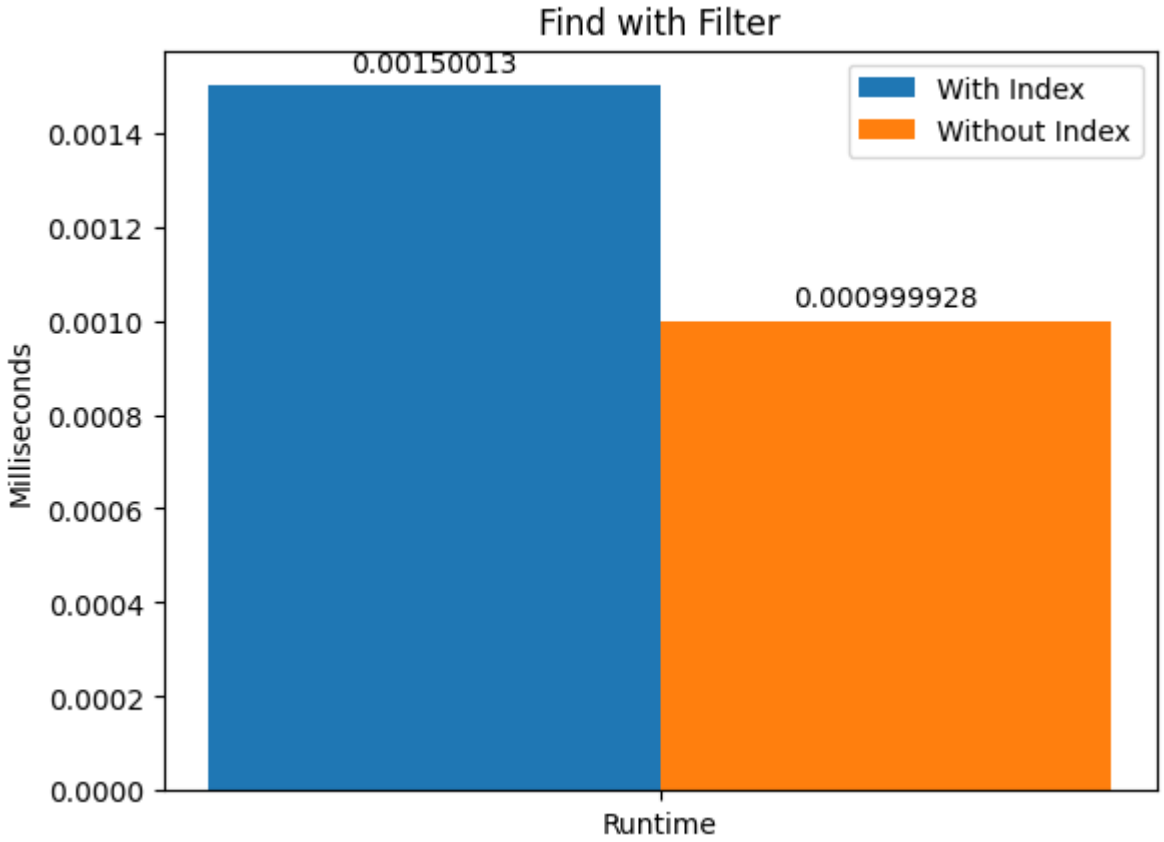
In [ ]:
```
create_plot_comparison(["Insert", "Find All"], [mongo_test_results["bulk_insertion_with_polls"], mongo_test_results["find_all"
```



The next plot compares the find performance of an indexed collection to an unindexed collection

Surprisingly the find operation on the indexed collection performs worse than the one on the unindexed collection when it comes to runtime.

In [ ]:
```
create_plot_comparison(["Runtime"], [mongo_index_test_results["find_filter"]], [mongo_test_results["find_filter"]], "With Inde
```

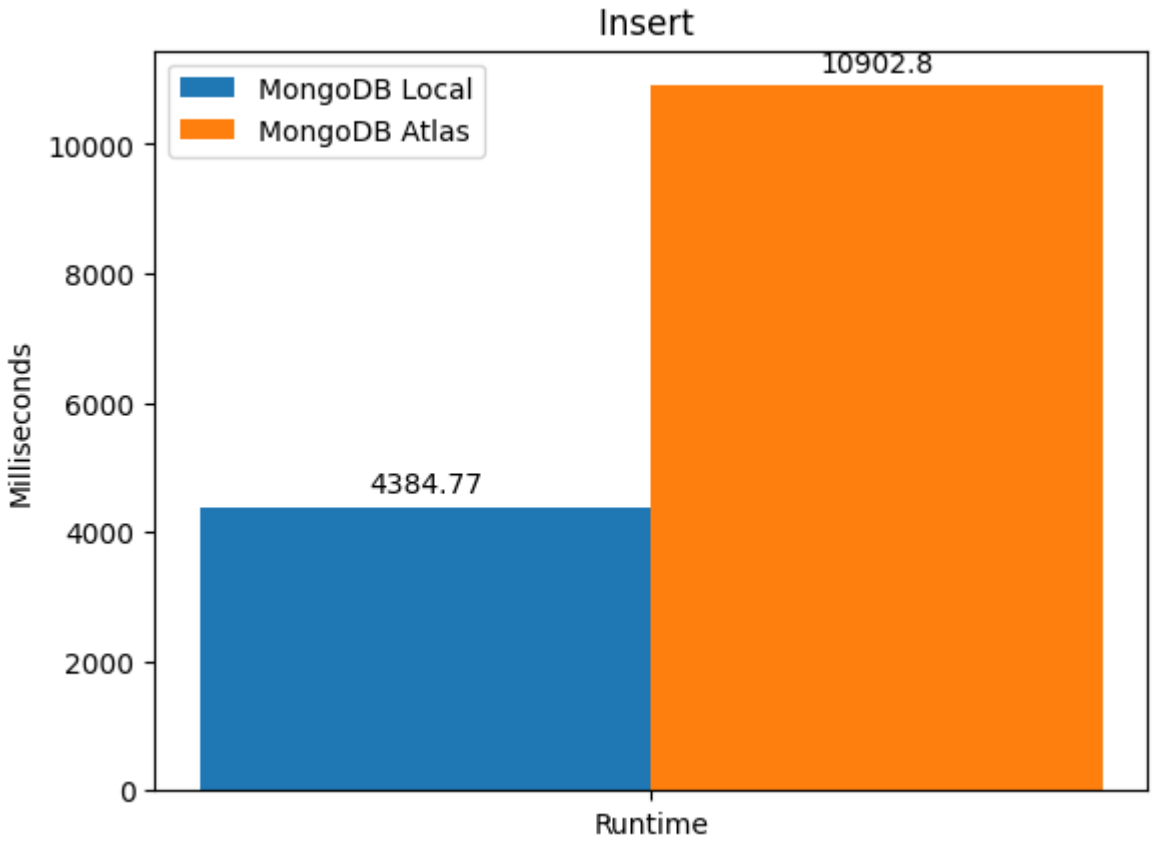


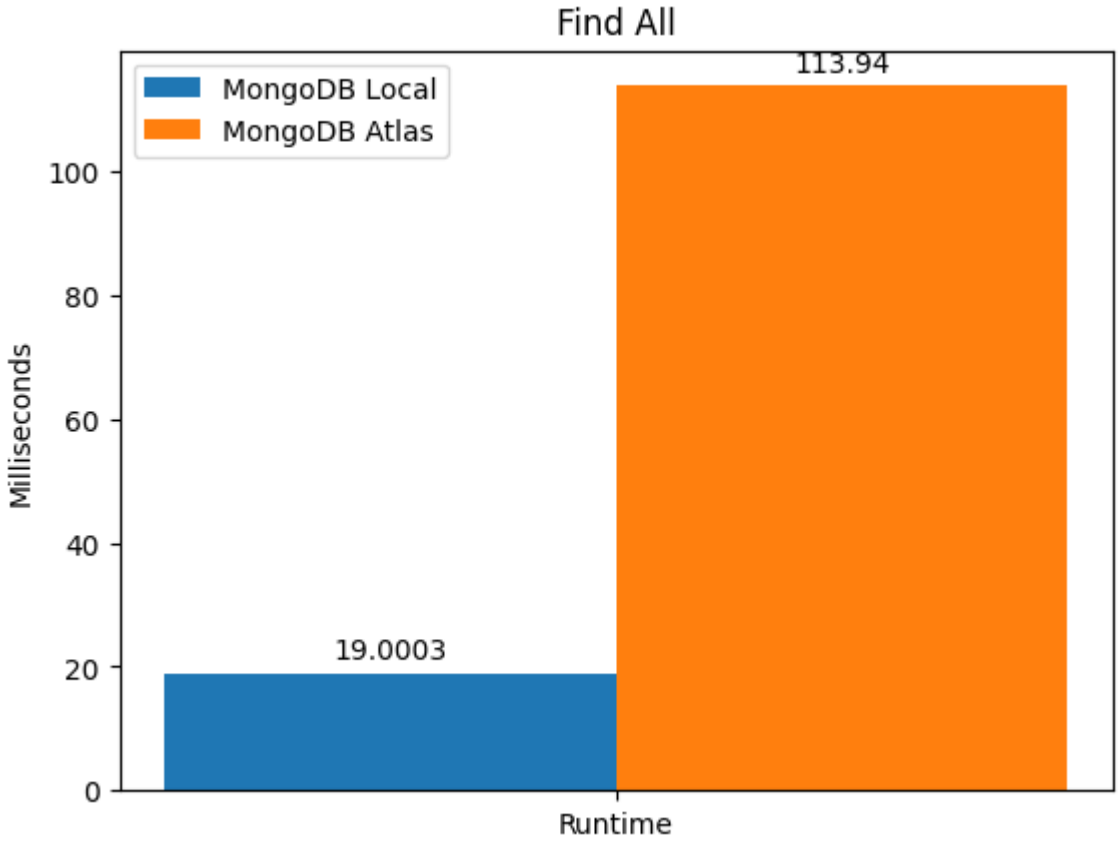
Tests running on local MongoDB instances compared to tests running on MongoDB Atlas

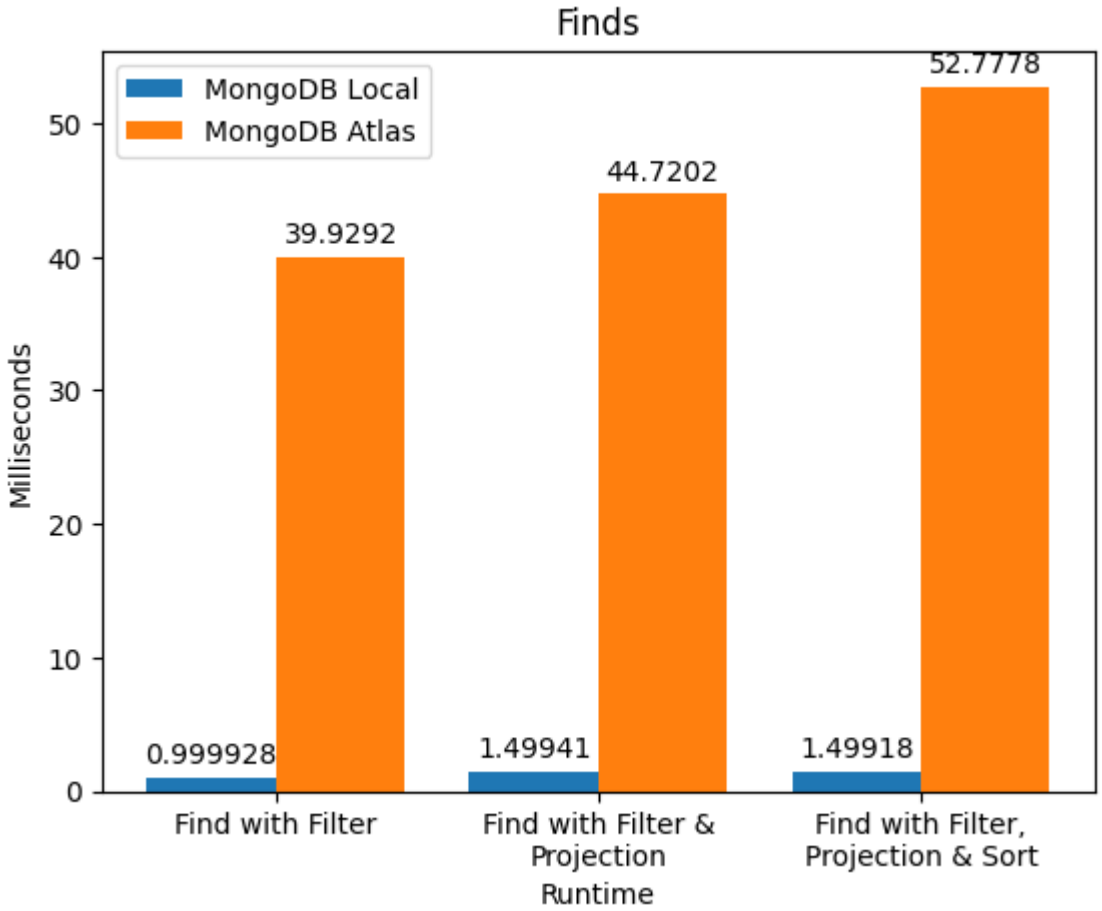
The operations on MongoDB Atlas seem to take a lot longer in terms of runtime, this can be explained by the latency of the internet connection which is non-existent when using the local MongoDB instance. Another factor could be that we are using the free shared cluster of MongoDB Atlas with lower performance than paid tiers.

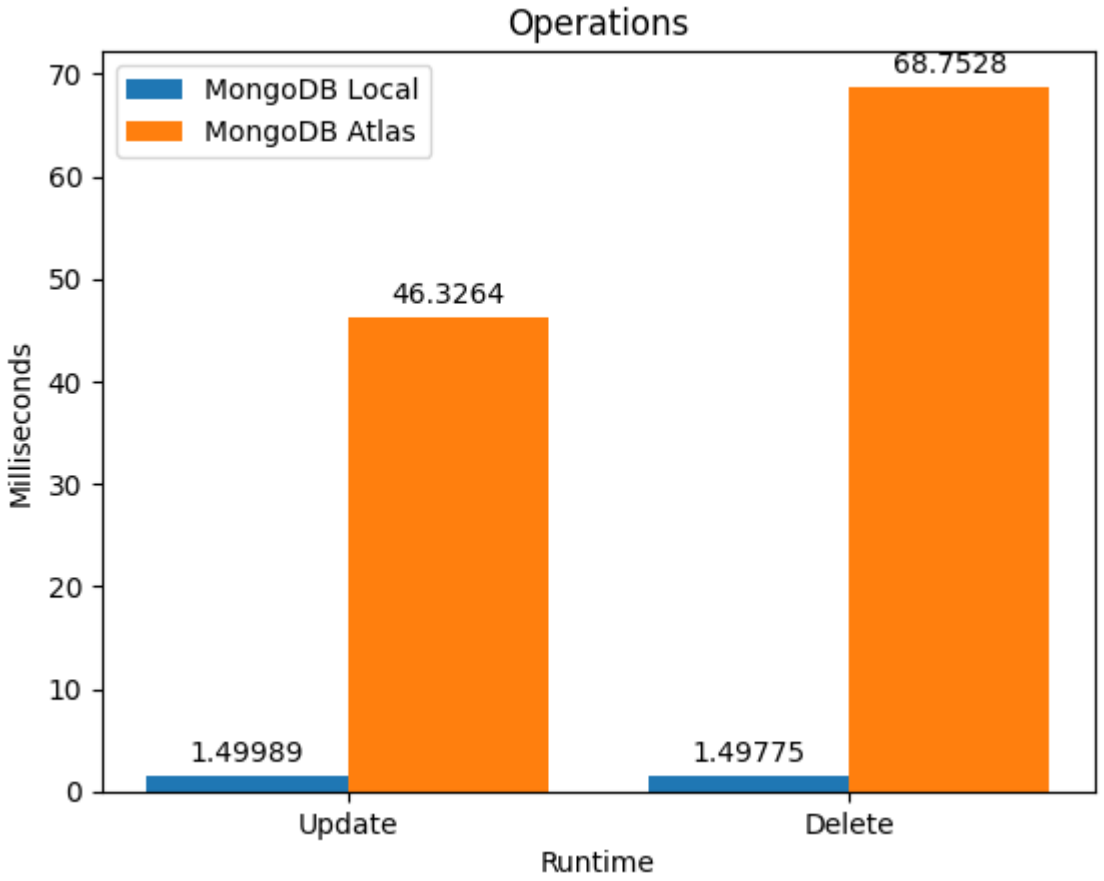
In [ ]:
```
create_plot_comparison(["Runtime"], [mongo_test_results["bulk_insertion"]*1000], [mongo_atlas_test_results["bulk_insertion"]*1

create_plot_comparison(["Runtime"], [mongo_test_results["find_all"]*1000], [mongo_atlas_test_results["find_all"]*1000], "Mongo
```

```
create_plot_comparison(["Find with Filter", "Find with Filter &\nProjection", "Find with Filter,\nProjection & Sort"], [mongo_

create_plot_comparison(["Update", "Delete"], [mongo_test_results["update"]*1000, mongo_test_results["delete"]*1000], [mongo_at
```




Find All
MongoDB Local
MongoDB Atlas
113.94
19.0003
Milliseconds
0
20
40
60
80
100
Runtime


Finds
MongoDB Local
MongoDB Atlas
Milliseconds
0
10
20
30
40
50
0.999928
39.9292
1.49941
44.7202
1.49918
52.7778
Find with Filter
Find with Filter & Projection
Find with Filter, Projection & Sort
Runtime

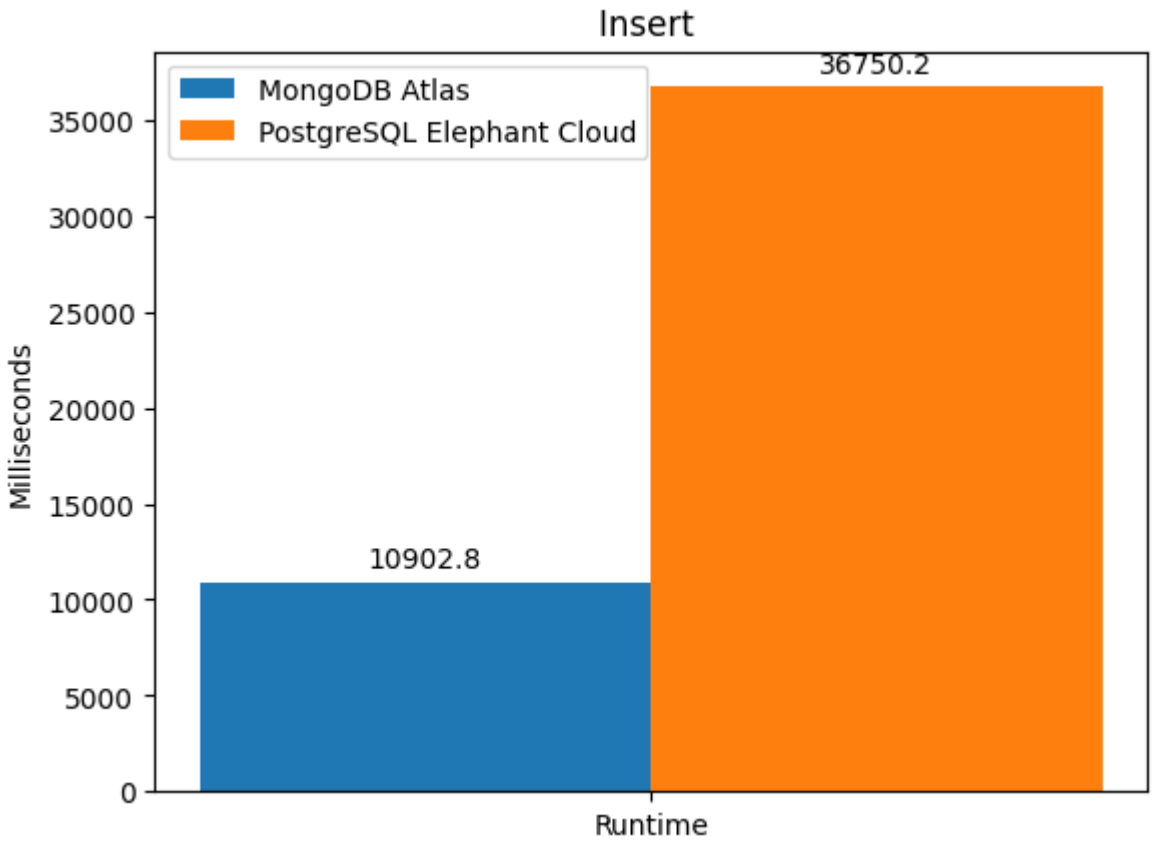


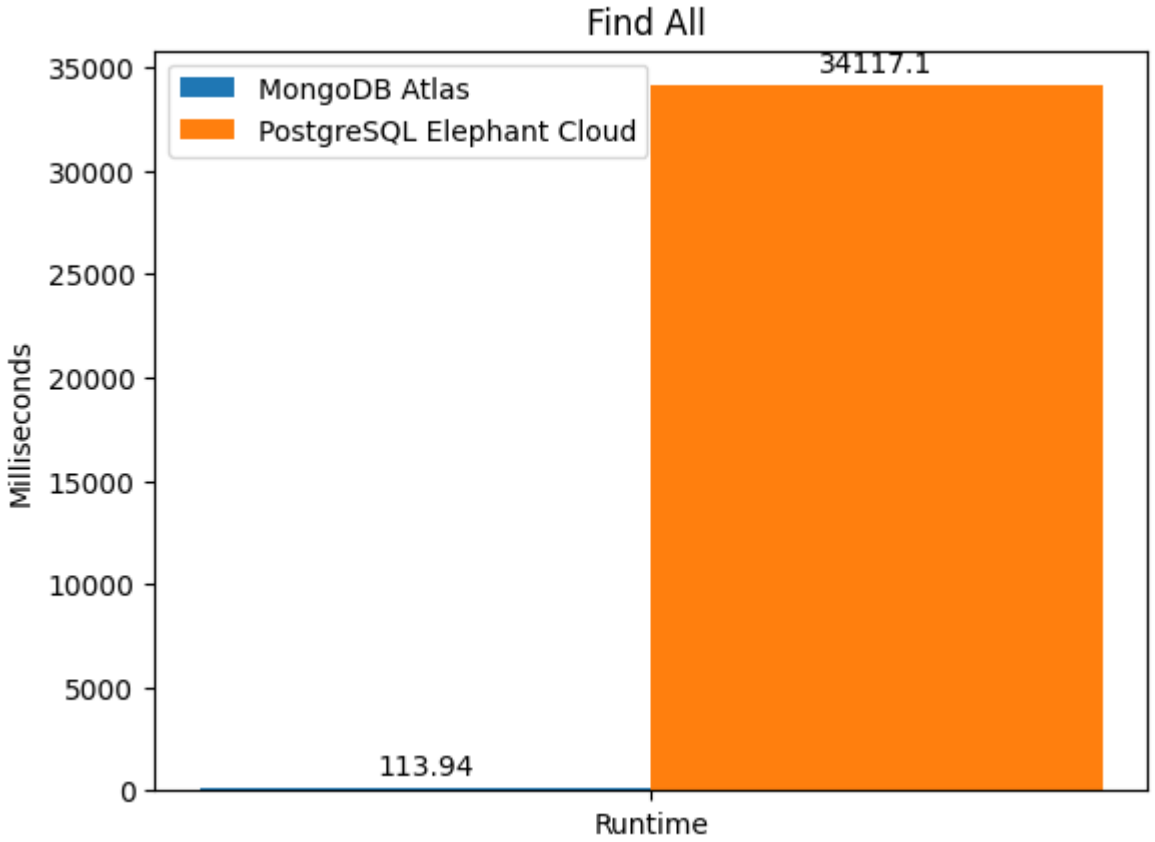
Tests running on MongoDB Atlas compared to PostgreSQL Elephant Cloud

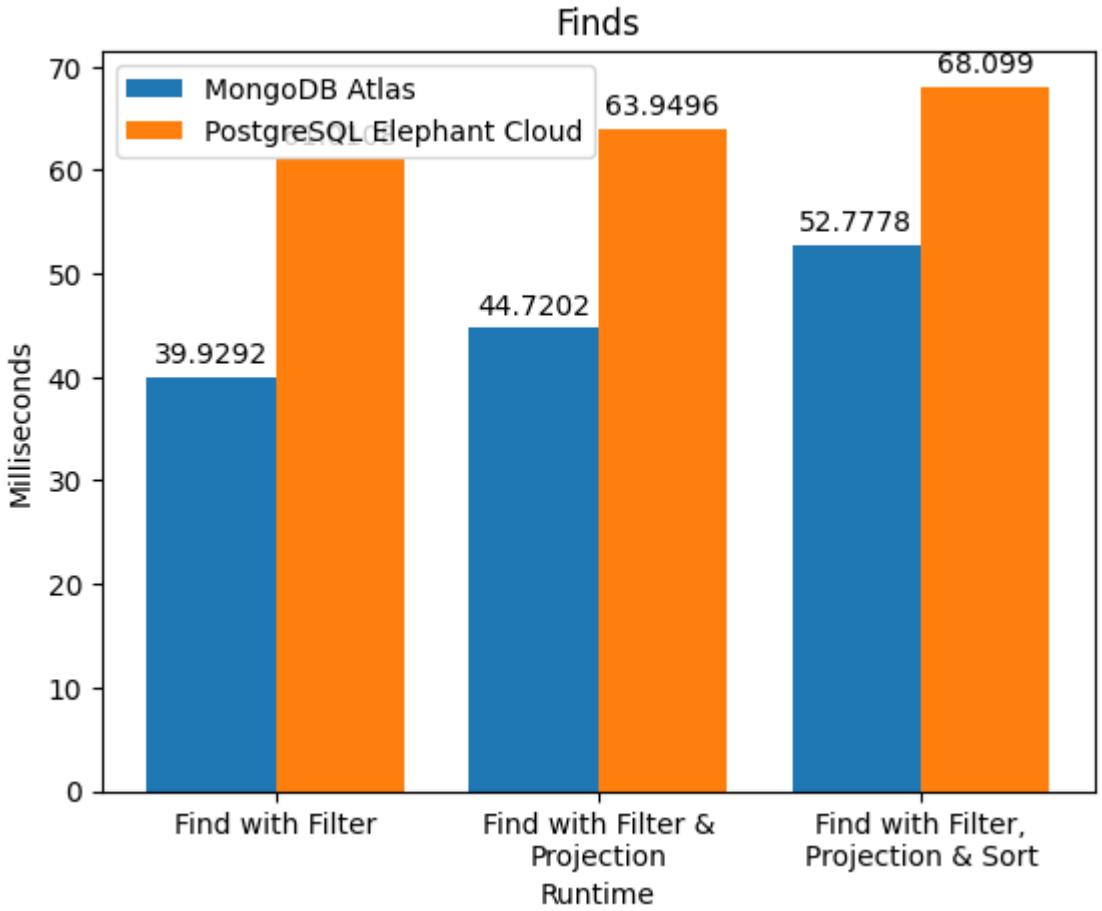
The runtime seems to be significantly lower on MongoDB Atlas, this may be due to MongoDB Atlas being a more popular cloud provider with more resources than Elpehant Cloud.

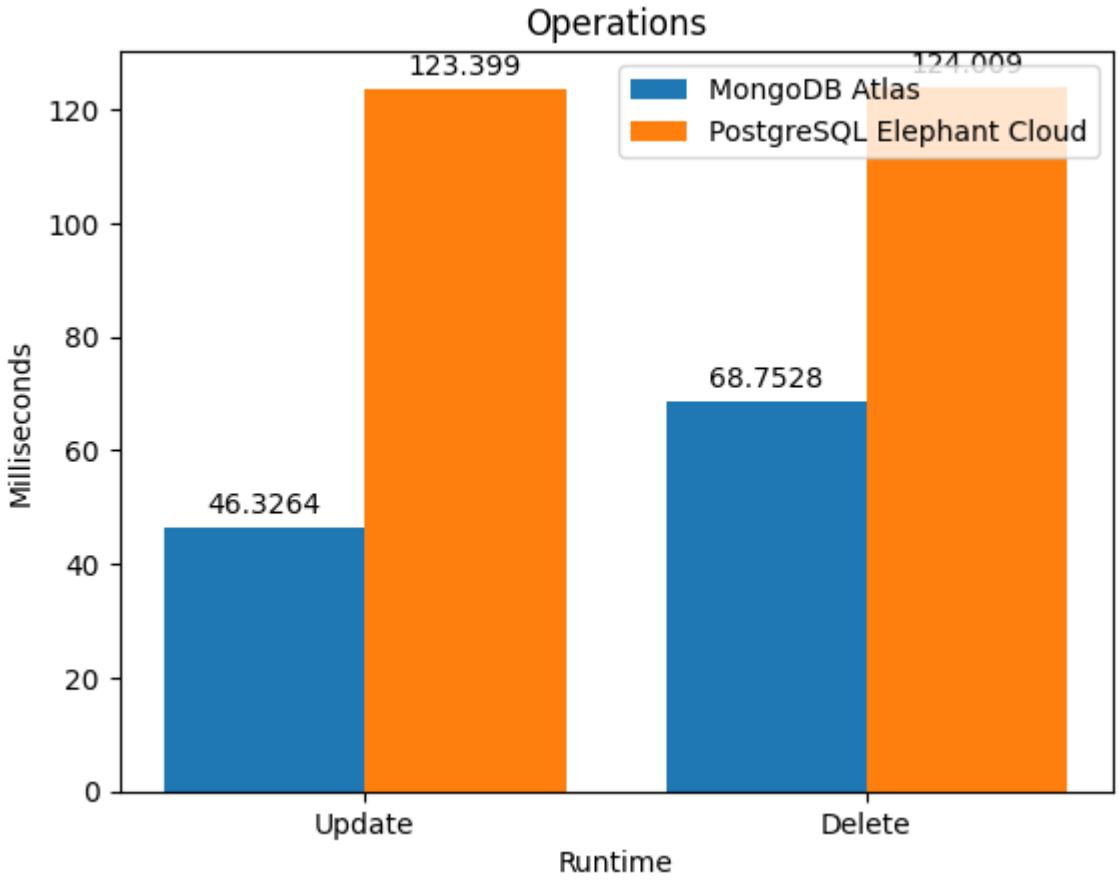
In [ ]:
```
create_plot_comparison(["Runtime"], [mongo_atlas_test_results["bulk_insertion"]*1000], [psql_cloud_test_results["bulk_insertio

create_plot_comparison(["Runtime"], [mongo_atlas_test_results["find_all"]*1000], [psql_cloud_test_results["find_all"]*1000], "

create_plot_comparison(["Find with Filter", "Find with Filter &\nProjection", "Find with Filter,\nProjection & Sort"], [mongo_
```

```
create_plot_comparison(["Update", "Delete"], [mongo_atlas_test_results["update"]*1000, mongo_atlas_test_results["delete"]*1000
```




Find All
MongoDB Atlas
PostgreSQL Elephant Cloud
34117.1
113.94
Milliseconds
35000
30000
25000
20000
15000
10000
5000
0
Runtime


Finds
MongoDB Atlas
PostgreSQL Elephant Cloud
Milliseconds
0
10
20
30
40
50
60
70
39.9292
63.9496
44.7202
52.7778
68.099
Find with Filter
Find with Filter & Projection
Find with Filter, Projection & Sort
Runtime


Operations
MongoDB Atlas
PostgreSQL Elephant Cloud
123.399
124.009
68.7528
46.3264
Milliseconds
0
20
40
60
80
100
120
Update
Delete
Runtime