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Stage 3 Submission

Database Implementation

```
flight_price_info=> \dt
             List of relations
 Schema |     Name      | Type  |  Owner
--------+---------------+-------+----------
 public | LegInfo       | table | postgres
 public | PricingInfo   | table | postgres
 public | ProfileInfo   | table | postgres
 public | RoundTripInfo | table | postgres
 public | humanuser     | table | postgres
(5 rows)

flight_price_info=>
```

We implemented five tables: note that `humanuser` is not trivial (it contains some login details, but also critical attribute information used in matching particular price results with specific traits for comparison in a key project component).

DDL Commands

```
CREATE TABLE IF NOT EXISTS LegInfo (
      leg_id SERIAL,
      date DATE,
      start_location TEXT,
      end_location TEXT,
      carrier TEXT,
      time TEXT,
      leg_length TEXT,
      stop_info TEXT,
      PRIMARY KEY (leg_id)
);

CREATE TABLE IF NOT EXISTS PricingInfo (
      price INT,
      seller TEXT,
      search_time TIMESTAMP,
      round_trip_id INT,
      profile_id INT,
      FOREIGN KEY (profile_id) REFERENCES ProfileInfo(profile_id),
```

```
      FOREIGN KEY (round_trip_id) REFERENCES RoundTripInfo(route_id)
);

CREATE TABLE IF NOT EXISTS RoundTripInfo (
      route_id SERIAL,
      name TEXT,
      leg_id1 INT,
      leg_id2 INT,
      start_location TEXT,
      end_location TEXT,
      PRIMARY KEY (route_id),
      FOREIGN KEY (leg_id1) REFERENCES LegInfo(leg_id),
      FOREIGN KEY (leg_id2) REFERENCES LegInfo(leg_id)
);

CREATE TABLE IF NOT EXISTS ProfileInfo (
      profile_id SERIAL NOT NULL,
      name TEXT,
      PRIMARY KEY (profile_id)
);

CREATE TABLE IF NOT EXISTS HumanUser (
      id INT NOT NULL,
      name VARCHAR(100),
      gender VARCHAR(10),
      age INT,
      zip VARCHAR(10),
      website_visited VARCHAR(100),
      password VARCHAR(100),
      PRIMARY KEY (id),
      FOREIGN KEY (id) REFERENCES ProfileInfo(profile_id) ON DELETE CASCADE
);
```

1,000 Rows Per Table Requirement

Per instructions, three of our four tables have at least 1000 rows:

```
flight_price_info=> SELECT COUNT(*) FROM "LegInfo";
 count
-------
 17065
(1 row)
```

Proof for `LegInfo` table.

```
flight_price_info=> SELECT COUNT(*) FROM "PricingInfo";
 count
--------
 237178
(1 row)
```

Proof for `PricingInfo` table.

```
flight_price_info=> SELECT COUNT(*) FROM "RoundTripInfo";
 count
-------
 16505
(1 row)
```

Proof for `RoundTripInfo` table.

Advanced Queries

AQ1: Average Round Trip Length for Each Departure/Starting Location

```sql
SELECT
    start_location,
    AVG(leg_1_length + leg_2_length) AS avg_roundtrip_length
FROM (
    SELECT
        start_location,
        (
            SELECT
                CAST(leg_length AS INTERVAL)
            FROM
                "LegInfo"
            WHERE
                leg_id = leg_id1
        ) AS leg_1_length,
        (
            SELECT
                CAST(leg_length AS INTERVAL)
            FROM
                "LegInfo"
            WHERE
                leg_id = leg_id2
        ) AS leg_2_length
    FROM
        "RoundTripInfo"
) as t
GROUP BY
    start_location
LIMIT
    15;
```

This query joins the roundtrip and its two travel leg information. And then, it will calculate the average `leg_length(travel duration)` of round trips for each `start_location`.

The query above satisfies the following advanced query requirements: joins multiple relations, aggregates via `GROUP BY`, and contains subqueries.

start_location	avg_roundtrip_length
9MY	12:28:51.428571
AFW	47:27:13.333333
ATL	05:57:05.806452
AUS	06:28:09.375
AZA	19:14:00
BDL	10:03:34.064516
BNA	07:56:43.231441
BUF	12:15:27.931034
BUR	23:18:20.917431
BWI	12:32:10.953347
BZN	16:37:40.754717
CHI	20:46:32.307692
CLT	03:00:07.272727
CMH	09:06:42
DEN	08:52:17.053942

(15 rows)

First 15 rows from the first advanced query.

AQ2: Calculate the Average Round Trip Price Each Sock Puppet Account Pays

```sql
SELECT
    name,
    ROUND(AVG(price / 100), 2) AS avg_price,
    COUNT(DISTINCT round_trip_id) AS num_round_trips
FROM
    "ProfileInfo"
NATURAL JOIN
    "PricingInfo"
GROUP BY
    profile_id
ORDER BY
    avg_price
LIMIT
    15;
```

This query joins the `ProfileInfo` and `PricingInfo` relation by joining on the shared column they have: `profile_id`. Once it's joined, group by using the `profile_id` to average the prices on all the round trips and count the number of unique round trips each profile queried. Finally, sort in descending order by the average price.

```
      name       | avg_price | num_round_trips
-----------------+-----------+-----------------
 senior_patagon  |    547.09 |            9438
 youth_patagon   |    563.53 |            9484
 senior          |    574.03 |            9543
 male_patagon    |    576.07 |            9642
 male            |    577.00 |            9493
 youth           |    584.47 |            9522
 control         |    585.52 |            9637
 female_patagon  |    589.11 |            9660
 female          |    591.47 |            9529
(9 rows)
```

The output of the second advanced query. Only 9 rows because there are only 9 sock puppet accounts.

Note: there are only 9 sock puppet accounts that have queried for round trips so the limit clause is pointless.

The query above satisfies the following requirements as specified on the rubric: joins multiple relations and aggregates via `GROUP BY`.

Indexing Analysis for AQ1

No Added Indices

```
                                                                 QUERY PLAN
--------------------------------------------------------------------------------------------------------------------------------------------
--------
 Limit  (cost=1443.28..65774.28 rows=15 width=20) (actual time=10.824..23.209 rows=15 loops=1)
   ->  GroupAggregate  (cost=1443.28..275922.23 rows=64 width=20) (actual time=10.822..23.205 rows=15 loops=1)
         Group Key: "RoundTripInfo".start_location
         ->  Sort  (cost=1443.28..1484.54 rows=16505 width=12) (actual time=10.683..10.930 rows=2935 loops=1)
               Sort Key: "RoundTripInfo".start_location
               Sort Method: quicksort  Memory: 1542kB
               ->  Seq Scan on "RoundTripInfo"  (cost=0.00..287.05 rows=16505 width=12) (actual time=0.019..2.857 rows=16505 loops=1)
         SubPlan 1
           ->  Index Scan using "LegInfo_pkey" on "LegInfo"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.002 rows=1 loops=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id1)
         SubPlan 2
           ->  Index Scan using "LegInfo_pkey" on "LegInfo" "LegInfo_1"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loop
s=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id2)
 Planning Time: 0.822 ms
 Execution Time: 23.426 ms
(15 rows)
```

Design 1
Create an index `start_location`

```
                                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------------------------------
----------
 Limit  (cost=0.29..64509.96 rows=15 width=20) (actual time=0.144..12.354 rows=15 loops=1)
   ->  GroupAggregate  (cost=0.29..275241.55 rows=64 width=20) (actual time=0.143..12.351 rows=15 loops=1)
         Group Key: "RoundTripInfo".start_location
         ->  Index Scan using idx_start_location on "RoundTripInfo"  (cost=0.29..803.86 rows=16505 width=12) (actual time=0.033..0.784 rows=2935
 loops=1)
         SubPlan 1
           ->  Index Scan using "LegInfo_pkey" on "LegInfo"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loops=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id1)
         SubPlan 2
           ->  Index Scan using "LegInfo_pkey" on "LegInfo" "LegInfo_1"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loop
s=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id2)
 Planning Time: 0.380 ms
 Execution Time: 12.430 ms
(12 rows)
```

After creating an index on the `start_location`, the query plan was more simplified and the performance was enhanced. In the query plan, sorting when grouping rows was removed because index already explains where each row is.

Design 2
Create an index on `start_location`, `leg_id1`

```
                                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------------------------------
----------
 Limit  (cost=0.29..64509.96 rows=15 width=20) (actual time=0.104..12.138 rows=15 loops=1)
   ->  GroupAggregate  (cost=0.29..275241.55 rows=64 width=20) (actual time=0.103..12.134 rows=15 loops=1)
         Group Key: "RoundTripInfo".start_location
         ->  Index Scan using idx_start_location on "RoundTripInfo"  (cost=0.29..803.86 rows=16505 width=12) (actual time=0.012..0.679 rows=2935
 loops=1)
         SubPlan 1
           ->  Index Scan using "LegInfo_pkey" on "LegInfo"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loops=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id1)
         SubPlan 2
           ->  Index Scan using "LegInfo_pkey" on "LegInfo" "LegInfo_1"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loop
s=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id2)
 Planning Time: 0.277 ms
 Execution Time: 12.191 ms
```

After adding an additional index on `leg_id1`, the query plan stayed the same, and the performance showed a negligible change.

Design 3
Create an index on `start_location`, `leg_id1`, `leg_id2`

```
                                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------------------------------
----------
 Limit  (cost=0.29..64509.96 rows=15 width=20) (actual time=0.225..12.833 rows=15 loops=1)
   ->  GroupAggregate  (cost=0.29..275241.55 rows=64 width=20) (actual time=0.224..12.829 rows=15 loops=1)
         Group Key: "RoundTripInfo".start_location
         ->  Index Scan using idx_start_location on "RoundTripInfo"  (cost=0.29..803.86 rows=16505 width=12) (actual time=0.123..0.921 rows=2935
 loops=1)
         SubPlan 1
           ->  Index Scan using "LegInfo_pkey" on "LegInfo"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.002 rows=1 loops=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id1)
         SubPlan 2
           ->  Index Scan using "LegInfo_pkey" on "LegInfo" "LegInfo_1"  (cost=0.29..8.31 rows=1 width=16) (actual time=0.001..0.001 rows=1 loop
s=2934)
                 Index Cond: (leg_id = "RoundTripInfo".leg_id2)
 Planning Time: 0.193 ms
 Execution Time: 12.889 ms
(12 rows)
```

After adding an additional index on `leg_id2`, the query plan stayed the same, and the performance showed a negligible change.

Conclusion

The final design for this query should be adding a single index on `start_location` field in table `RoundTrip`. Sorting by a grouping key is necessary to group a table if that key is indexed. However, if we index that key in the table, it is possible to group rows by that key without sorting. This makes a huge improvement on the performance because otherwise the sorting would have been done with the entire rows. However, indexing `leg_id1` or `leg_id2` had no impact in the optimization. Adding an index might be beneficial in the query performance, but it also degrades the performance when inserting/updating rows. Therefore, the final design should be only indexing `start_location` field.

Indexing Analysis for AQ2

No Added Indices

```
                                   QUERY PLAN
---------------------------------------------------------------------------------------------
 Limit  (cost=35481.25..35481.29 rows=15 width=76) (actual time=218.588..218.592 rows=9 loops=1)
   ->  Sort  (cost=35481.25..35484.43 rows=1270 width=76) (actual time=218.586..218.589 rows=9 loops=1)
         Sort Key: (round(avg(("PricingInfo".price / 100)), 2))
         Sort Method: quicksort  Memory: 25kB
         ->  GroupAggregate  (cost=29495.24..35450.09 rows=1270 width=76) (actual time=107.659..218.560 rows=9 loops=1)
               Group Key: "ProfileInfo".profile_id
               ->  Merge Join  (cost=29495.24..33059.26 rows=237178 width=44) (actual time=93.619..160.119 rows=237178 loops=1)
                     Merge Cond: ("PricingInfo".profile_id = "ProfileInfo".profile_id)
                     ->  Sort  (cost=29407.07..30000.02 rows=237178 width=12) (actual time=93.585..117.551 rows=237178 loops=1)
                           Sort Key: "PricingInfo".profile_id
                           Sort Method: external merge  Disk: 5128kB
                           ->  Seq Scan on "PricingInfo"  (cost=0.00..4175.78 rows=237178 width=12) (actual time=0.008..41.635 rows=237178 loops=
1)
                     ->  Sort  (cost=88.17..91.35 rows=1270 width=36) (actual time=0.028..0.037 rows=9 loops=1)
                           Sort Key: "ProfileInfo".profile_id
                           Sort Method: quicksort  Memory: 25kB
                           ->  Seq Scan on "ProfileInfo"  (cost=0.00..22.70 rows=1270 width=36) (actual time=0.013..0.016 rows=13 loops=1)
 Planning Time: 0.189 ms
 Execution Time: 220.141 ms
(18 rows)
```

Design 1

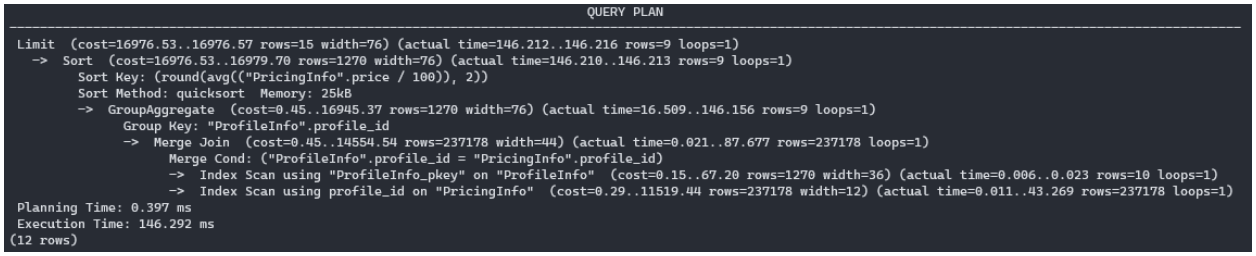
Create an index for `profile_id` in `PricingInfo`.

```
                                   QUERY PLAN
---------------------------------------------------------------------------------------------
 Limit  (cost=16976.53..16976.57 rows=15 width=76) (actual time=146.873..146.876 rows=9 loops=1)
   ->  Sort  (cost=16976.53..16979.70 rows=1270 width=76) (actual time=146.872..146.874 rows=9 loops=1)
         Sort Key: (round(avg(("PricingInfo".price / 100)), 2))
         Sort Method: quicksort  Memory: 25kB
         ->  GroupAggregate  (cost=0.45..16945.37 rows=1270 width=76) (actual time=17.135..146.837 rows=9 loops=1)
               Group Key: "ProfileInfo".profile_id
               ->  Merge Join  (cost=0.45..14554.54 rows=237178 width=44) (actual time=0.050..87.498 rows=237178 loops=1)
                     Merge Cond: ("ProfileInfo".profile_id = "PricingInfo".profile_id)
                     ->  Index Scan using "ProfileInfo_pkey" on "ProfileInfo"  (cost=0.15..67.20 rows=1270 width=36) (actual time=0.008..0.023 rows=10 loops=1)
                     ->  Index Scan using profile_id on "PricingInfo"  (cost=0.29..11519.44 rows=237178 width=12) (actual time=0.037..44.057 rows=237178 loops=1)
 Planning Time: 0.327 ms
 Execution Time: 146.984 ms
(12 rows)
```

Creating an index for profile_id in PricingInfo substantially reduces the execution time of the second advanced query. Looking at the produced execution tree, we can see that the merge condition is simplified from the tree produced with no added indices. That is indicative of the performance gains we see in the final time.

Design 2

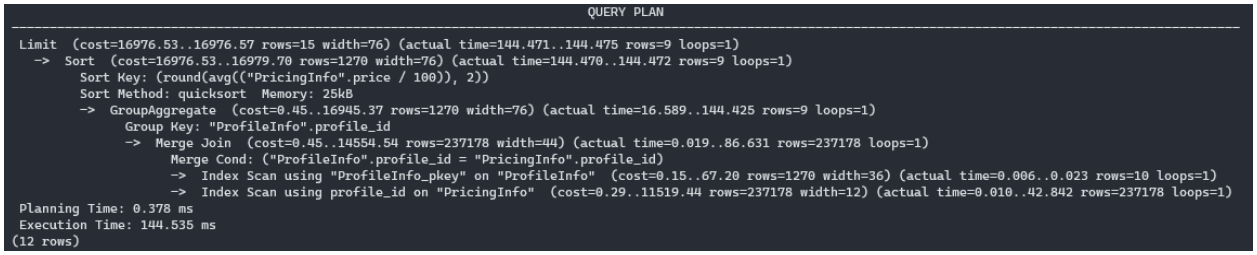
Create an index for `profile_id` and `price` in `PricingInfo`.



There seems to be no improvement when we add a `price` index to the `PricingInfo` relation. When calculating the average, there's not really a need to read the prices in a specific order because you're going to read all the prices for a given user profile no matter what to get an accurate average. It makes sense that the performance is nearly identical to the previous design that uses only the `profile_id` index.

Design 3

Create an index for `profile_id`, `price`, and `round_trip_id` in `PricingInfo`.



Similar to what we saw in Design 2, we see negligible differences in execution time and the trees produced during the planning process. It seems that only `profile_id` helped. One theory for this outcome could be that all prices and round trip IDs need to be read, so there's not really a point in having those indexed because we're not looking for a particular subset. However, that justification could also be used with `profile_id`, but the `profile_id` could still be helpful because that's the field we're grouping by, so the index still could provide some utility when performing other operation in the query.

Conclusion

For the final implementation, we will keep only the `profile_id` in the `PricingInfo` relation for now given the results we saw above with the second advanced query. It may be helpful to re-add the fields above if new queries are going to be regularly used, only `profile_id` seems useful. All other indices were negligible. We can see that the `profile_id` index is being used in the last two steps where an index scan on `profile_id` is being performed. Without that index, the database couldn't have performed an index scan resulting in a more intensive algorithm to produce the same results. In short, given the near identical performance of Design 1, 2, and 3, we will only keep the `profile_id` index unless other queries call for new indices.