Lab 3: Tables and Data

In this lab, we will cover the following topics:

- Handling objects with quoted names
- Enforcing the same name and definition for columns
- Identifying and removing duplicates
- Preventing duplicate rows
- Finding a unique key for a set of data
- Generating test data
- Loading data from a spreadsheet
- Loading data from flat files
- Making bulk data changes using server-side procedures with transactions

Handling objects with quoted names

PostgreSQL object names can contain spaces and mixed-case characters if we enclose the table names in double quotes. This can cause some difficulties and security issues, so this topic is designed to help you if you get stuck with this kind of problem.

Case-sensitivity issues can often be a problem for people more used to working with other database systems, such as MySQL, or for people who are facing the challenge of migrating code away from MySQL.

Getting ready

First, let's create a table that uses a quoted name with mixed cases, such as the following:

```
CREATE TABLE cust (
 customerid BIGINT NOT NULL
,firstname TEXT NOT NULL
,lastname TEXT NOT NULL
,age INTEGER NOT NULL);

INSERT INTO cust VALUES (1, 'Philip', 'Marlowe', 33);
INSERT INTO cust VALUES (2, 'Richard', 'Hannay', 37);
INSERT INTO cust VALUES (3, 'Harry', 'Palmer', 36);
INSERT INTO cust VALUES (4, 'Rick', 'Deckard', 4);
INSERT INTO cust VALUES (4, 'Roy', 'Batty', 41);


CREATE TABLE "MyCust"
AS
SELECT * FROM cust;
```

How to do it...

If we try to access these tables without the proper case, we get this error:

```
postgres=# SELECT count(*) FROM mycust;

ERROR:   relation "mycust" does not exist
LINE 1: SELECT * FROM mycust;
```

So, we write it in the correct case:

```
postgres=# SELECT count(*) FROM MyCust;

ERROR:  relation "mycust" does not exist
LINE 1: SELECT * FROM mycust;
```

This still fails and, in fact, gives the same error.

If you want to access a table that was created with quoted names, then you must use quoted names, such as the following:

```
postgres=# SELECT count(*) FROM "MyCust";
```

The output is as follows:

```
count | 5
```

The usage rule is that if you create your tables using quoted names, then you need to write your SQL using quoted names. Alternatively, if your SQL uses quoted names, then you will probably have to create the tables using quoted names as well.

How it works...

PostgreSQL folds all names to lowercase when used within an SQL statement. Consider this command:

```
SELECT * FROM mycust;
```

This is exactly the same as the following command:

```
SELECT * FROM MYCUST;
```

It is also exactly the same as this command:

```
SELECT * FROM MyCust;
```

However, it is not the same thing as the following command:

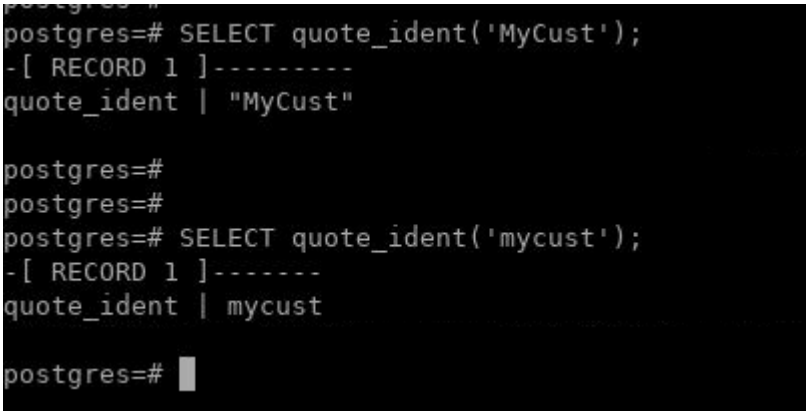
```
SELECT * FROM "MyCust";
```

There's more...

If you are handling object names in SQL, then you should use `quote_ident()` to ensure users don't call their objects a name that could cause security issues. `quote_ident()` puts double quotes around a value if PostgreSQL requires that for an object name, as shown here:

```
postgres=# SELECT quote_ident('MyCust');

postgres=# SELECT quote_ident('mycust');
```



Enforcing the same name and definition for columns

Sensibly designed databases have smooth, easy-to-understand definitions. This allows all users to understand the meaning of data in each table. It is an important way of removing data quality issues.

Getting ready

If you want to run the queries in this topic as a test, then use the following examples. Alternatively, you can just check for problems in your own database:

```
CREATE SCHEMA s1;
CREATE SCHEMA s2;
CREATE TABLE s1.X(col1 smallint,col2 TEXT);
CREATE TABLE s2.X(col1 integer,col3 NUMERIC);
```

How to do it...

First, we will show you how to identify columns that are defined in different ways in different tables, using a query against the catalog. We will use an `information_schema` query, as follows:

```
SELECT
 table_schema
,table_name
,column_name
,data_type
  ||coalesce(' ' || text(character_maximum_length), '')
  ||coalesce(' ' || text(numeric_precision), '')
  ||coalesce(',' || text(numeric_scale), '')
  as data_type
FROM information_schema.columns
WHERE column_name IN
(SELECT
 column_name
 FROM
 (SELECT
  column_name
  ,data_type
```

```
  ,character_maximum_length
  ,numeric_precision
  ,numeric_scale
  FROM information_schema.columns
  WHERE table_schema NOT IN ('information_schema', 'pg_catalog')
  GROUP BY
   column_name
  ,data_type
  ,character_maximum_length
  ,numeric_precision
  ,numeric_scale
 ) derived
 GROUP BY column_name
 HAVING count(*) > 1
)
AND table_schema NOT IN ('information_schema', 'pg_catalog')
ORDER BY column_name;
```

The query gives an output, as follows:

```
 table_schema | table_name | column_name |   data_type
--------------+------------+-------------+---------------
 s1           | x          | col1        | smallint 16,0
 s2           | x          | col1        | integer 32,0
(2 rows)
```

Comparing two given tables is more complex, as there are so many ways that the tables might be similar and yet a little different. The following query looks for all tables of the same name (and, hence, in different schemas) that have different definitions:

```
WITH table_definition as
( SELECT table_schema
       , table_name
       , string_agg( column_name || ' ' || data_type
                   , ',' ORDER BY column_name
                   ) AS def
    FROM information_schema.columns
   WHERE table_schema NOT IN ( 'information_schema'
                             , 'pg_catalog')
   GROUP BY table_schema
          , table_name
)
  , unique_definition as
( SELECT DISTINCT table_name
       , def
    FROM table_definition
)
   , multiple_definition as
( SELECT table_name
    FROM unique_definition
   GROUP BY table_name
  HAVING count( * ) > 1
)
```

```
SELECT table_schema
     , table_name
     , column_name
     , data_type
  FROM information_schema.columns
 WHERE table_name
       IN ( SELECT table_name
              FROM multiple_definition )
 ORDER BY table_name
        , table_schema
        , column_name;
```

Here is its output:

```
 table_schema | table_name | column_name | data_type
--------------+------------+-------------+-----------
 s1           | x          | col1        | smallint
 s1           | x          | col2        | text
 s2           | x          | col1        | integer
 s2           | x          | col3        | numeric
(4 rows)
```

How it works...

The definitions of tables are held within PostgreSQL and can be accessed using the information schema catalog views.

There might be valid reasons why the definitions differ. We've excluded PostgreSQL's own internal tables because there are similar names between the two catalogs: PostgreSQL's implementation of the SQL standard information schema and PostgreSQL's own internal `pg_catalog` schema.

Those queries are fairly complex. In fact, there is even more complexity that we can add to those queries to compare all sorts of things, such as default values or constraints. The basic idea can be extended in various directions from here.

There's more...

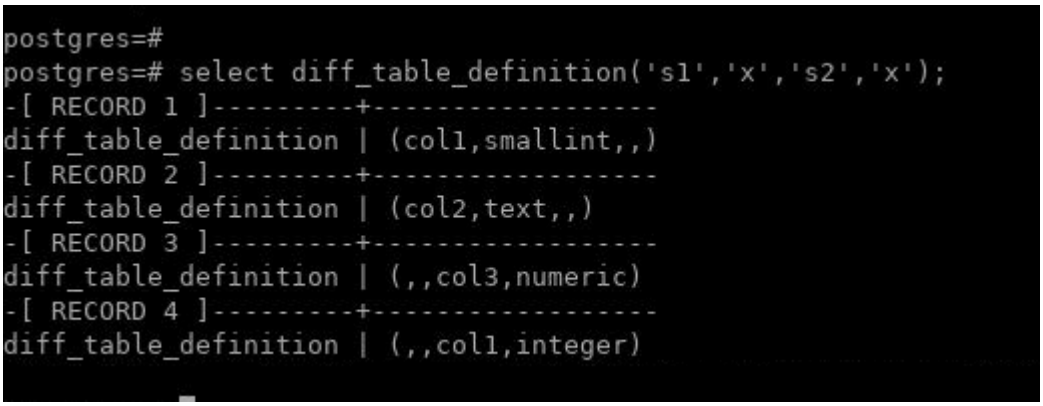
We can compare the definitions of any two tables using the following function:

```
CREATE OR REPLACE FUNCTION diff_table_definition
(t1_schemaname text
,t1_tablename text
,t2_schemaname text
,t2_tablename text)
RETURNS TABLE
(t1_column_name text
,t1_data_type text
,t2_column_name text
,t2_data_type text)
LANGUAGE SQL
as
$$
SELECT
```

```
 t1.column_name
,t1.data_type
,t2.column_name
,t2.data_type
FROM
 (SELECT column_name, data_type
  FROM information_schema.columns
  WHERE table_schema = $1
      AND table_name = $2
 ) t1
FULL OUTER JOIN
 (SELECT column_name, data_type
  FROM information_schema.columns
  WHERE table_schema = $3
      AND table_name = $4
 ) t2
ON t1.column_name = t2.column_name
AND t1.data_type = t2.data_type
WHERE t1.column_name IS NULL OR t2.column_name IS NULL
;
$$;
```

Here is its usage with output:

```
select diff_table_definition('s1','x','s2','x');
```



Identifying and removing duplicates

Relational databases work on the idea that items of data can be uniquely identified. However hard we try, there will always be bad data arriving from somewhere. This topic shows you how to diagnose that and clean up the mess.

Getting ready

Let's start by looking at an example table, `cust`. It has a duplicate value in `customerid`:

```
postgres=# SELECT * FROM cust ORDER BY 1;
```

```
 customerid | firstname | lastname | age
------------+-----------+----------+-----
          1 | Philip    | Marlowe  |  33
          2 | Richard   | Hannay   |  37
          3 | Harry     | Palmer   |  36
          4 | Rick      | Deckard  |  4
          4 | Roy       | Batty    |  41
(5 rows)
```

Before you delete duplicate data, remember that sometimes it isn't the data that is wrong -- it is your understanding of it. In those cases, it may be that you haven't properly normalized your database model and that you need to include additional tables to account for the shape of the data. You might also find that duplicate rows are caused because of your decision to exclude a column somewhere earlier in a data load process. Check twice, cut once.

How to do it...

First, identify the duplicates using a query, such as the following:

```
CREATE UNLOGGED TABLE dup_cust AS
SELECT *
FROM cust
WHERE customerid IN
 (SELECT customerid
  FROM cust
  GROUP BY customerid
  HAVING count(*) > 1);
```

We save the list of duplicates in a separate table because the query can be very slow if the table is big, so we don't want to run it more than once.

An `UNLOGGED` table can be created with less I/O because it does not write WAL. It is better than a temporary table because it doesn't disappear if you disconnect and then reconnect. The other side of the coin is that you lose its contents after a crash, but this is not too bad because if you are choosing to use an unlogged table, then you are telling PostgreSQL that you are able to recreate the contents of that table in the (unlikely) event of a crash.

The results can be used to identify the bad data manually, and you can resolve the problem by carrying out the following steps:

1. Merge the two rows to give the best picture of the data, if required. This might use values from one row to update the row you decide to keep, as shown here:

   ```
   UPDATE cust
   SET age = 41
   WHERE customerid = 4
   AND lastname = 'Deckard';
   ```

2. Delete the remaining undesirable rows:

   ```
   DELETE FROM cust
   WHERE customerid = 4
   AND lastname = 'Batty';
   ```

In some cases, the data rows might be completely identical, so let's create an example:

```
CREATE TABLE new_cust (customerid BIGINT NOT NULL);
INSERT INTO new_cust VALUES (1), (1), (2), (3), (4), (4);
```

The `new_cust` table looks like the following:

```
postgres=# SELECT * FROM new_cust ORDER BY 1;
 customerid
------------
          1
          2
          3
          4
          4
(5 rows)
```

Unlike the preceding case, we can't tell the data apart at all, so we cannot remove duplicate rows without any manual process. SQL is a set-based language, so picking only one row out of a set is slightly harder than most people want it to be.

In these circumstances, we should use a slightly different procedure to detect duplicates. We will use a hidden column named `ctid`. It denotes the physical location of the row you are observing -- for example, duplicate rows will all have different `ctid` values. The steps are as follows:

1. First, we start a transaction:

   ```
   BEGIN;
   ```

2. Then, we lock the table in order to prevent any `INSERT`, `UPDATE`, or `DELETE` operations, which would alter the list of duplicates and/or change their `ctid` values:

   ```
   LOCK TABLE new_cust IN SHARE ROW EXCLUSIVE MODE;
   ```

3. Now, we locate all duplicates, keeping track of the minimum `ctid` value so that we don't delete it:

   ```
   CREATE TEMPORARY TABLE dups_cust AS
   SELECT customerid, min(ctid) AS min_ctid
   FROM new_cust
   GROUP BY customerid
   HAVING count(*) > 1;
   ```

4. Then, we can delete each duplicate, with the exception of the duplicate with the minimum `ctid` value:

   ```
   DELETE FROM new_cust
   USING dups_cust
   WHERE new_cust.customerid = dups_cust.customerid
   AND new_cust.ctid != dups_cust.min_ctid;
   ```

5. We commit the transaction, which also releases the lock we previously took:

   ```
   COMMIT;
   ```

6. Finally, we clean up the table after the deletions:

   ```
   VACUUM new_cust;
   ```

How it works...

The first query works by grouping together the rows on the unique column and counting rows. Anything with more than one row must be caused by duplicate values. If we're looking for duplicates of more than one column (or even all columns), then we have to use a SQL query of the following form:

```
SELECT *
FROM mytable
WHERE  (col1, col2, ... ,colN) IN
(SELECT col1, col2, ... ,colN
 FROM mytable
 GROUP BY  col1, col2, ... ,colN
 HAVING count(*) > 1);
```

Here, `col1`, `col2`, and so on up until `colN` are the columns of the key.

Note that this type of query may need to sort the complete table on all the key columns. That will require sort space equal to the size of the table, so you'd better think first before running that SQL on very large tables. You'll probably benefit from a large `work_mem` setting for this query, probably 128 MB or more.

The `DELETE FROM ... USING` query that we showed only works with PostgreSQL because it uses the `ctid` value, which is the internal identifier of each row in the table. If you wanted to run that query against more than one column, as we did earlier in the lab, you'd need to extend the queries in *step 3*, as follows:

```
SELECT customerid, customer_name, ..., min(ctid) AS min_ctid
FROM ...
GROUP BY customerid, customer_name, ...
...;
```

Then, extend the query in *step 4*, like this:

```
DELETE FROM new_cust
...
WHERE new_cust.customerid = dups_cust.customerid
AND new_cust.customer_name = dups_cust.customer_name
AND ...
AND new_cust.ctid != dups_cust.min_ctid;
```

The preceding query works by grouping together all the rows with similar values and then finding the row with the lowest `ctid` value. The lowest will be closer to the start of the table, so duplicates will be removed from the far end of the table. When we run `VACUUM`, we may find that the table gets smaller because we have removed rows from the far end.

The `BEGIN` and `COMMIT` commands wrap the `LOCK` and `DELETE` commands into a single transaction, which is required. Otherwise, the lock will be released immediately after being taken.

Another reason to use a single transaction is that we can always roll back if anything goes wrong, which is a good thing when we are removing data from a live table.

Preventing duplicate rows

Preventing duplicate rows is one of the most important aspects of data quality for any database. PostgreSQL offers some useful features in this area, extending beyond most relational databases.

Getting ready

Identify the set of columns that you wish to make unique. Does this apply to all rows or just a subset of rows?

Let's start with our example table:

```
postgres=# SELECT * FROM new_cust;
 customerid
------------
          1
          2
          3
          4
(4 rows)
```

How to do it...

To prevent duplicate rows, we need to create a unique index that the database server can use to enforce the uniqueness of a particular set of columns. We can do this in the following three similar ways for basic data types:

1. Create a primary key constraint on the set of columns. We are allowed only one of these per table. The values of the data rows must not be `NULL`, as we force the columns to be `NOT NULL` if they aren't already:

```
ALTER TABLE new_cust ADD PRIMARY KEY(customerid);
```

This creates a new index named `new_cust_pkey`.

1. Create a unique constraint on the set of columns. We can use these instead of/or with a primary key. There is no limit on the number of these per table. `NULL` values are allowed in the columns:

```
ALTER TABLE new_cust ADD UNIQUE(customerid);
```

This creates a new index named `new_cust_customerid_key`.

1. Create a unique index on the set of columns:

```
CREATE UNIQUE INDEX ON new_cust (customerid);
```

This creates a new index named `new_cust_customerid_idx`.

All these techniques exclude duplicates, just with slightly different syntaxes. All of them create an index, but only the first two create a formal *constraint*. Each of these techniques can be used when we have a primary key or unique constraint that uses multiple columns.

The last method is important because it allows you to specify a `WHERE` clause on the index. This can be useful if you know that the column values are unique only in certain circumstances. The resulting index is then known as a **partial index**.

Let's start with the simplest example: create a table of boxes and put sample data in it. This may be the first time you're seeing PostgreSQL's data type syntax, so bear with me:

```
postgres=# CREATE TABLE boxes (name text, position box);
CREATE TABLE
postgres=# INSERT INTO boxes VALUES
                          ('First', box '((0,0), (1,1))');
INSERT 0 1
postgres=# INSERT INTO boxes VALUES
                          ('Second', box '((2,0), (2,1))');
INSERT 0 1
postgres=# SELECT * FROM boxes;
  name  |  position
--------+-------------
 First  | (1,1),(0,0)
 Second | (2,1),(2,0)
(2 rows)
```

We can see two boxes that neither touch nor overlap, based on their *x* and *y* coordinates.

To enforce uniqueness here, we want to create a constraint that will throw out any attempt to add a position that overlaps with any existing box. The overlap operator for the box data type is defined as `&&`, so we use the following syntax to add the constraint:

```
ALTER TABLE boxes ADD EXCLUDE USING gist (position WITH &&);
```

This creates a new index named `boxes_position_excl`:

```
 #\d boxes_position_excl
```

```
postgres=# ALTER TABLE boxes ADD EXCLUDE USING gist (position WITH &&);
ALTER TABLE
postgres=#  #\d boxes_position_excl
 Index "public.boxes_position_excl"
  Column  | Type | Key? | Definition
----------+------+------+------------
 position | box  | yes  | "position"
gist, for table "public.boxes"
```

We can use the same syntax even with the basic data types. So, a fourth way of performing our first example would be as follows:

```
ALTER TABLE new_cust ADD EXCLUDE (customerid WITH =);
```

This creates a new index named `new_cust_customerid_excl`, and duplicates are excluded:

```
insert into new_cust VALUES (4);
```

```
postgres=# insert into new_cust VALUES (4);
ERROR:  duplicate key value violates unique constraint "new_cust_pkey"
DETAIL:  Key (customerid)=(4) already exists.
postgres=#
```

How it works...

Uniqueness is always enforced by an index.

Each index is defined with a data type operator. When a new row is inserted or the set of column values is updated, we use the operator to search for existing values that conflict with the new data.

So, to enforce uniqueness, we need an index and a search operator defined on the data types of the columns. When we define normal `UNIQUE` constraints, we simply assume that we mean the equality operator (`=`) for the data type. The `EXCLUDE` syntax offers a richer syntax to allow us to express the same problem with different data types and operators.

There's more...

Unique and exclusion constraints can be marked as deferrable, meaning that a user can choose to postpone the check to the end of the transaction -- a nice way to relax constraints without reducing data integrity.

Duplicate indexes

Note that PostgreSQL allows you to have multiple indexes with exactly the same definition. This is useful in some contexts but can also be annoying if you accidentally create multiple indexes, as each index has its own cost in terms of writes. You can also have constraints defined using each of the aforementioned different ways. Each of these ways enforces, essentially, the same constraint, so take care.

Uniqueness without indexes

It's possible to have uniqueness in a set of columns without creating an index. That might be useful if all we want is to ensure uniqueness rather than allow index lookups.

To do that, you can do either of the following:

- Use a serial data type.
- Manually alter the default to be the `nextval()` function of a sequence.

Each of these will provide a unique value for use as a row's key. The uniqueness is not enforced, nor will there be a unique constraint defined. So, there is still a possibility that someone might reset the sequence to an earlier value, which will eventually cause duplicate values.

Consider, also, that this method provides the unique value as a default, which is not used when a user specifies an explicit value. An example of this is as follows:

```
CREATE TABLE t(id serial, descr text);
INSERT INTO t(descr) VALUES ('First value');
INSERT INTO t(id,descr) VALUES (1,'Cheating!');
```

Finally, you might also wish to have mostly unique data, such as using the `clock_timestamp()` function to provide ascending times to a microsecond resolution.

A real-world example -- IP address range allocation

The problem is about assigning ranges of IP addresses while at the same time ensuring that we don't allocate (or potentially allocate) the same addresses to different people or purposes. This is easy to do if we keep track of each individual IP address but much harder to do if we want to deal solely with ranges of IP addresses.

Initially, you may think of designing the database as follows:

```
CREATE TABLE iprange
 (iprange_start inet
 ,iprange_stop inet
 ,owner text);
INSERT INTO iprange VALUES ('192.168.0.1','192.168.0.16', 'Simon');
INSERT INTO iprange VALUES ('192.168.0.17','192.168.0.24', 'Gianni');
INSERT INTO iprange VALUES ('192.168.0.32','192.168.0.64', 'Gabriele');
```

However, you'll realize that there is no way to create a unique constraint that enforces the model constraint of avoiding overlapping ranges. You can create an after trigger that checks existing values, but it's going to be messy.

PostgreSQL offers a better solution, based on *range types*. In fact, every data type that supports a `btree` operator class (that is, a way of ordering any two given values) can be used to create a range type. In our case, the SQL is as follows:

```
CREATE TYPE inetrange AS RANGE (SUBTYPE = inet);
```

This command creates a new data type that can represent ranges of `inet` values -- that is, of IP addresses. Now, we can use this new type when creating a table:

```
CREATE TABLE iprange2
(iprange inetrange
,owner text);
```

This new table can be populated as usual. We just have to group the extremes of each range into a single value, as follows:

```
INSERT INTO iprange2 VALUES ('[192.168.0.1,192.168.0.16]', 'Simon');
INSERT INTO iprange2 VALUES ('[192.168.0.17,192.168.0.24]', 'Gianni');
INSERT INTO iprange2 VALUES ('[192.168.0.32,192.168.0.64]', 'Gabriele');
```

Now, we can create a *unique exclusion constraint* on the table, using the following syntax:

```
ALTER TABLE iprange2
 ADD EXCLUDE USING GIST (iprange WITH &&);
```

If we try to insert a range that overlaps with any of the existing ranges, then PostgreSQL will stop us:

```
INSERT INTO iprange2
VALUES ('[192.168.0.10,192.168.0.20]', 'Somebody else');
```

```
postgres=# INSERT INTO iprange2 VALUES ('[192.168.0.1,192.168.0.16]', 'Simon');
INSERT 0 1
postgres=# INSERT INTO iprange2 VALUES ('[192.168.0.17,192.168.0.24]', 'Gianni');
INSERT 0 1
postgres=# INSERT INTO iprange2 VALUES ('[192.168.0.32,192.168.0.64]', 'Gabriele');
INSERT 0 1
postgres=# ALTER TABLE iprange2
postgres-#  ADD EXCLUDE USING GIST (iprange WITH &&);
ALTER TABLE
postgres=# INSERT INTO iprange2
postgres-# VALUES ('[192.168.0.10,192.168.0.20]', 'Somebody else');
ERROR:  conflicting key value violates exclusion constraint "iprange2_iprange_excl"
DETAIL:  Key (iprange)=([192.168.0.10,192.168.0.20]) conflicts with existing key (iprange)=([192.168.0.1,192.168.0.16]).
postgres=#
```

A real-world example -- a range of time

In many databases, there will be historical data tables with data that has a `START_DATE` value and an `END_DATE` value, or something similar. As in the previous example, we can solve this problem elegantly with a range type. Actually, this example is even shorter -- we don't need to create the range type, since the most common cases are already built-in -- that is, integers, decimal values, dates, and timestamps with and without a time zone.

Finding a unique key for a set of data

Sometimes, it can be difficult to find a unique set of key columns that describe the data. In this topic, we will analyze the data in the database to allow us to identify the column(s) that together form a unique key. This is useful when a key is not documented, not defined, or has been defined incorrectly.

Getting ready

Let's start with a small table, where the answer is fairly obvious:

```
CREATE TABLE ord (
orderid INTEGER NOT NULL
,customerid INTEGER NOT NULL
,amt INTEGER NOT NULL
);

INSERT INTO ord VALUES (10677, 2, 6);
INSERT INTO ord VALUES (5019, 3, 277);
INSERT INTO ord VALUES (9748, 3, 77);

select * from ord;
```

We assume that the output is as follows:

```
orderid  | customerid |  amt
---------+------------+--------
   10677 |          2 |   5.50
    5019 |          3 | 277.44
    9748 |          3 |  77.17
(3 rows)
```

How to do it...

First of all, there's no need to do this through a brute-force approach. Checking all the permutations of columns to see which is unique might take you a long time.

Let's start by using PostgreSQL's own optimizer statistics. Run the following command on the table to get a fresh sample of statistics:

```
postgres=# analyze ord;
ANALYZE
```

This runs quickly, so we don't have to wait too long. Now, we can examine the relevant columns of the statistics:

```
postgres=# SELECT attname, n_distinct
                           FROM pg_stats
                           WHERE schemaname = 'public'
                           AND tablename = 'ord';
  attname   | n_distinct
------------+------------
 orderid    |         -1
 customerid |  -0.666667
 amt        |         -1
(3 rows)
```

The preceding example was chosen because we have two potential answers. If the value of `n_distinct` is `-1`, then the column is thought to be unique within the sample of rows examined.

We will then need to use our judgment to decide whether one or both of these columns are unique by chance or as part of the design of the database that created them.

It's possible that there is no single column that uniquely identifies the rows. Multiple column keys are fairly common. If none of the columns were unique, then we should start looking for unique keys that are combinations of the most unique columns. The following query shows a frequency distribution for the table where a value occurs twice in one case and another value occurs only once:

```
postgres=# SELECT num_of_values, count(*)
            FROM (SELECT customerid, count(*) AS num_of_values
                        FROM ord
                        GROUP BY customerid) s
            GROUP BY num_of_values
            ORDER BY count(*);
 num_of_values | count
---------------+-------
             4 |     1
             2 |     1
```

We can change the query to include multiple columns, like this:

```
SELECT num_of_values, count(*)
FROM (SELECT   customerid, orderid, amt
              ,count(*) AS num_of_values
               FROM ord
               GROUP BY customerid, orderid, amt
               ) s
GROUP BY num_of_values
ORDER BY count(*);
```

When we find a set of columns that is unique, this query will result in only one row, as shown in the following example:

```
 num_of_values | count
---------------+-------
             2 |     3
```

As we get closer to finding the key, we will see that the distribution gets tighter and tighter.

So, the procedure is as follows:

1. Choose one column to start with.
2. Compute the corresponding frequency distribution.
3. If the outcome is multiple rows, then add one more column and repeat from *step 2*. Otherwise, it means you have found a set of columns satisfying a uniqueness constraint.

Now, you must verify that the set of columns is minimal -- for example, check whether it is possible to remove one or more columns without violating the unique constraint. This can be done using the frequency distribution as a test. To be precise, do the following:

1. Test each column by computing the frequency distribution on all the other columns.
2. If the frequency distribution has one row, then the column is not needed in the uniqueness constraint. Remove it from the set of columns and repeat from *step 1*. Otherwise, you have found a minimal set of columns, which is also called a key for that table.

How it works...

Finding a unique key is possible for a program, but in most cases, a human can do this much faster by looking at things such as column names, foreign keys, or business understanding to reduce the number of searches required by the brute-force approach.

The `ANALYZE` command works by taking a sample of the table data and then performing a statistical analysis of the results. The `n_distinct` value has two different meanings, depending on its sign: if positive, it is the estimate of the number of distinct values for the column; if negative, it is the estimate of the density of such distinct values, with the sign changed. For example, `n_distinct = -0.2` means that a table of 1 million rows is expected to have 200,000 distinct values, while `n_distinct = 5` means that we expect just 5 distinct values.

Generating test data

DBAs frequently need to generate test data for a variety of reasons, whether it's for setting up a test database or just for generating a test case for a SQL performance issue.

How to do it...

To create a table of test data, we need the following:

- Some rows
- Some columns
- Some order

The steps are as follows:

1. First, generate a lot of rows of data. We use something named a `set-returning` function. You can write your own, though PostgreSQL includes a couple of very useful ones.

2. You can generate a sequence of rows using a query like the following:

```
postgres=# SELECT * FROM generate_series(1,5);
```

```
 generate_series
-----------------
               1
               2
               3
               4
               5
(5 rows)
```

3. Alternatively, you can generate a list of dates, like this:

```
postgres=# SELECT date(t)
FROM generate_series(now(),
  now() + '1 week', '1 day') AS f(t);
```

```
    date
------------
 2021-08-25
 2021-08-26
 2021-08-27
 2021-08-28
 2021-08-29
 2021-08-30
 2021-08-31
 2021-09-01
(8 rows)
```

Loading data from a spreadsheet

Spreadsheets are the most obvious starting place for most data stores. Studies within a range of businesses consistently show that more than 50% of smaller data stores are held in spreadsheets or small desktop databases. Loading data from these sources is a frequent and important task for many DBAs.

Getting ready

Spreadsheets combine data, presentation, and programs all into one file. That's perfect for power users wanting to work quickly. As with other relational databases, PostgreSQL is mainly concerned with the lowest level of data, so extracting just data from these spreadsheets can present some challenges.

We can easily handle spreadsheet data if that spreadsheet's layout follows a very specific form, as follows:

- Each spreadsheet column becomes one column in one table.

- Each row of the spreadsheet becomes one row in one table.
- Data is only in one worksheet of the spreadsheet.
- Optionally, the first row is a list of column descriptions/titles.

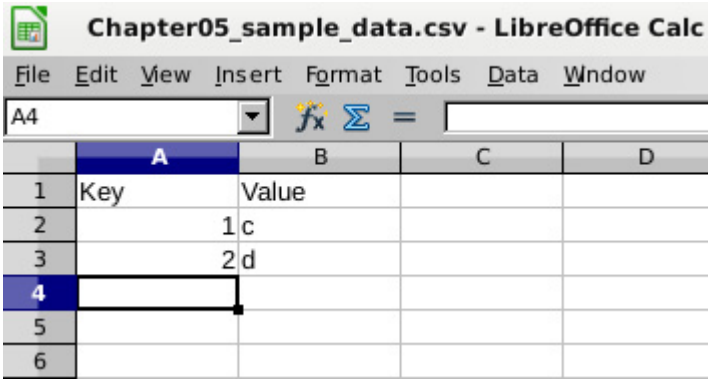
This is a very simple layout, and more often, there will be other things in the spreadsheet, such as titles, comments, constants for use in formulas, summary lines, macros, and images. If you're in this position, the best thing to do is to create a new worksheet within the spreadsheet in the pristine form described earlier and then set up cross-worksheet references to bring in the data. An example of a cross-worksheet reference would be `=Sheet2.A1`. You'll need a separate worksheet for each set of data, which will become one table in PostgreSQL. You can load multiple worksheets into one table, however.

Some spreadsheet users will say that all of this is unnecessary and is evidence of the problems of databases. The real spreadsheet gurus do actually advocate this type of layout -- data in one worksheet and calculation and presentation in other worksheets. So, it is actually a best practice to design spreadsheets in this way; however, we must work with the world the way it is.

How to do it...

Here, we will show you an example where data in a spreadsheet is loaded into a database:

1. If your spreadsheet data is neatly laid out in a single worksheet, as shown in the following screenshot, then you can go to **File** | **Save As** and then select **CSV** as the file type to be saved:



1. This will export the current worksheet to a file, as follows:

```
"Key","Value"
1,"c"
2,"d"
```

2. We can then create a table to load the data into, using psql and the command:

```
CREATE TABLE example
(key integer
,value text);
```

3. We can then load it into the PostgreSQL table, using the following `psql` command:

```
postgres=# \COPY sample FROM sample.csv CSV HEADER
postgres=# SELECT * FROM sample;
 key | value
-----+-------
```

```
  1 | c
  2 | d
```

4. Alternatively, from the command line, this would be as follows:

```
psql -c '\COPY sample FROM sample.csv CSV HEADER'
```

The filename can include a full file path if the data is in a different directory. The `psql \COPY` command transfers data from the client system where you run the command through to the database server, so the file is on the client. Higher privileges are not required, so this is the preferred method.

1. If you are submitting SQL through another type of connection, then you can also use the following SQL statement of the form, noting that the leading backslash is removed:

```
COPY sample FROM '/mydatafiledirectory/sample.csv' CSV HEADER;
```

The `COPY` statement shown in the preceding SQL statement uses an absolute path to identify data files, which is required. This method runs on the database server and can only be executed by a super user, or a user who has been granted one of the `pg_read_server_files`, `pg_write_server_files`, or `pg_execute_server_program` roles. So, you need to ensure that the server process is allowed to read that file, then transfer the data yourself to the server, and finally, load the file. These privileges are not commonly granted, which is why we prefer the earlier method.

The `COPY` (or `\COPY`) command does not create the table for you; that must be done beforehand. Note also that the `HEADER` option does nothing but ignore the first line of the input file, so the names of the columns from the `.csv` file don't need to match those of the `Postgres` table. If it hasn't occurred to you yet, this is also a problem. If you say `HEADER` and the file does not have a header line, then all it does is ignore the first data row. Unfortunately, there's no way for PostgreSQL to tell whether the first line of the file is truly a header or not. Be careful!

There isn't a standard tool to load data directly from the spreadsheet to the database. It's fairly simple to write a spreadsheet macro to automate the aforementioned tasks, but that's not a topic for this book.

How it works...

The `\COPY` command executes a `COPY` SQL statement, so the two methods described earlier are very similar. There's more to be said about `COPY`, so we'll cover that in the next topic.

Under the covers, the `\COPY` command executes a `COPY … FROM STDIN` command. When using this form of command, the client program must read the file and feed the data to the server. psql does this for you, but in other contexts, you can use this mechanism to avoid the need for higher privileges or additional roles, which are needed when running `COPY` with an absolute filename.

There's more...

There are many data extraction and loading tools available out there, some cheap and some expensive. Remember that the hardest part of loading data from any spreadsheet is separating the data from all the other things it contains. I've not yet seen a tool that can help with that! This is why the best practice for spreadsheets is to separate data into separate worksheets.

Loading data from flat files

Loading data into your database is one of the most important tasks. You need to do this accurately and quickly. Here's how.

Getting ready

For basic loading, `COPY` works well for many cases, including CSV files, as shown in the last topic.

If you want advanced functionality for loading, you may wish to try `pgloader`, which is commonly available in all main software distributions. At the time of writing, the current stable version is 3.6.3. There are many features, but it is stable, with very few new features in recent years.

How to do it...

To load data with `pgloader`, we need to understand our requirements, so let's break this down into a step-by-step process, as follows:

1. Identify the data files and where they are located. Make sure that `pgloader` is installed in the location of the files.
2. Identify the table into which you are loading, ensure that you have the permissions to load, and check the available space. Work out the file type (examples include fixed-size fields, delimited text, and CSV) and check the encoding.
3. Specify the mapping between columns in the file and columns on the table being loaded. Make sure you know which columns in the file are not needed -- `pgloader` allows you to include only the columns you want. Identify any columns in the table for which you don't have data. Do you need them to have a default value on the table, or does `pgloader` need to generate values for those columns through functions or constants?
4. Specify any transformations that need to take place. The most common issue is date formats, although it's possible that there may be other issues.
5. Write the `pgloader` script.
6. The `pgloader` script will create a log file to record whether the load has succeeded or failed, and another file to store rejected rows. You need a directory with sufficient disk space if you expect them to be large. Their size is roughly proportional to the number of failing rows.
7. Finally, consider what settings you need for performance options. This is definitely last, as fiddling with things earlier can lead to confusion when you're still making the load work correctly.
8. You must use a script to execute `pgloader`. This is not a restriction; actually, it is more like a best practice, because it makes it much easier to iterate toward something that works. Loads never work the first time, except in the movies!

Let's look at a typical example from the quick-start documentation of `pgloader`, the `csv.load` file.

Define the required operations in a command and save it in a file, such as `csv.load`:

```
LOAD CSV
   FROM '/tmp/file.csv' (x, y, a, b, c, d)
   INTO postgresql://postgres@localhost:5432/postgres?csv (a, b, d, c)
     WITH truncate,
          skip header = 1,
          fields optionally enclosed by '"',
          fields escaped by double-quote,
          fields terminated by ','
      SET client_encoding to 'latin1',
          work_mem to '12MB',
```

```
         standard_conforming_strings to 'on'
  BEFORE LOAD DO
   $$ drop table if exists csv; $$,
   $$ create table csv (
       a bigint,
       b bigint,
       c char(2),
       d text
      );
 $$;
```

This command allows us to load the following CSV file content. Save this in a file, such as `file.csv`, under the `/tmp` directory:

```
Header, with a © sign
"2.6.190.56","2.6.190.63","33996344","33996351","GB","United Kingdom"
"3.0.0.0","4.17.135.31","50331648","68257567","US","United States"
"4.17.135.32","4.17.135.63","68257568","68257599","CA","Canada"
"4.17.135.64","4.17.142.255","68257600","68259583","US","United States"
"4.17.143.0","4.17.143.15","68259584","68259599","CA","Canada"
"4.17.143.16","4.18.32.71","68259600","68296775","US","United States"
```

We can use the following `load` script:

```
pgloader csv.load
```

Here's what gets loaded in the PostgreSQL database:

```
postgres=# select * from csv;
    a     |    b     | c  |     d
----------+----------+----+----------------
 33996344 | 33996351 | GB | United Kingdom
 50331648 | 68257567 | US | United States
 68257568 | 68257599 | CA | Canada
 68257600 | 68259583 | US | United States
 68259584 | 68259599 | CA | Canada
 68259600 | 68296775 | US | United States
(6 rows)
```

How it works...

`pgloader` copes gracefully with errors. The `COPY` command loads all rows in a single transaction, so only a single error is enough to abort the load. `pgloader` breaks down an input file into reasonably sized chunks and loads them piece by piece. If some rows in a chunk cause errors, then `pgloader` will split it iteratively until it loads all the good rows and skips all the bad rows, which are then saved in a separate rejects file for later inspection. This behavior is very convenient if you have large data files with a small percentage of bad rows -- for instance, you can edit the rejects, fix them, and finally, load them with another `pgloader` run.

Versions from the 2.x iteration of `pgloader` were written in Python and connected to PostgreSQL through the standard Python client interface. Version 3.x is written in Common Lisp. Yes, `pgloader` is less efficient than loading data files using a `COPY` command, but running a `COPY` command has many more restrictions: the file has to be in the right place on the server, has to be in the right format, and must be unlikely to throw errors on

loading. `pgloader` has additional overhead, but it also has the ability to load data using multiple parallel threads, so it can be faster to use as well. The ability of `pgloader` to reformat the data via user-defined functions is often essential; a straight `COPY` command may not be enough.

`pgloader` also allows loading from fixed-width files, which `COPY` does not.

If you need to reload the table completely from scratch, then specify the `WITH TRUNCATE` clause in the `pgloader` script.

There are also options to specify SQL to be executed before and after loading data. For instance, you can have a script that creates the empty tables before, you can add constraints after, or both.

There's more...

After loading, if we have load errors, then there will be bloat in the PostgreSQL tables. You should think about whether you need to add a `VACUUM` command after the data load, though this will possibly make the load take much longer.

We need to be careful to avoid loading data twice. The only easy way of doing so is to make sure that there is at least one unique index defined on every table that you load. The load should then fail very quickly.

String handling can often be difficult because of the presence of formatting or non-printable characters. The default setting for PostgreSQL is to have a parameter named `standard_conforming_strings` set to `off`, which means that backslashes will be assumed to be escape characters. Put another way, by default, the `\n` string means a line feed, which can cause data to appear truncated. You'll need to turn `standard_conforming_strings` to `on`, or you'll need to specify an escape character in the load-parameter file.

If you are reloading data that has been unloaded from PostgreSQL, then you may want to use the `pg_restore` utility instead. The `pg_restore` utility has an option to reload data in parallel, `-j number_of_threads`, though this is only possible if the dump was produced using the custom `pg_dump` format.

If you need to use rows from a read-only text file that does not have errors, then you may consider using the `file_fdw` contrib module. The short story is that it lets you create a *virtual* table that will parse the text file every time it is scanned. This is different from filling a table once and for all, either with `COPY` or `pgloader`; therefore, it covers a different use case. For example, think about an external data source that is maintained by a third party and needs to be shared across different databases.

Another option would be EDB*Loader, which also contains a wide range of load options: https://www.enterprisedb.com/docs/epas/latest/epas_compat_tools_guide/02_edb_loader/.

Making bulk data changes using server-side procedures with transactions

In cases, you'll need to make bulk changes to your data. In many cases, you need to scroll through the data making changes according to a complex set of rules. You have a few choices in that case:

- Write a single SQL statement that can do everything.
- Open a cursor and read the rows out, and then make changes with a client-side program.
- Write a procedure that uses a cursor to read the rows and make changes using server-side SQL.

Writing a single SQL statement that does everything is sometimes possible, but if you need to do more than just use `UPDATE`, then it becomes difficult very quickly. The main difficulty is that the SQL statement isn't restartable, so if you need to interrupt it, you will lose all of your work.

Reading all the rows back to a client-side program can be very slow -- if you need to write this kind of program, it is better to do it all on the database server.

Getting ready

Create an example table and fill it with nearly 1,000 rows of test data:

```
CREATE TABLE employee (
 empid     BIGINT NOT NULL PRIMARY KEY
,job_code  TEXT NOT NULL
,salary    NUMERIC NOT NULL
);
INSERT INTO employee VALUES (1, 'A1', 50000.00);
INSERT INTO employee VALUES (2, 'B1', 40000.00);
INSERT INTO employee SELECT generate_series(10,1000), 'A2', 10000.00);
```

How to do it...

We're going to write a procedure in PL/pgSQL. A procedure is similar to a function, except that it doesn't return any value or object. We use a procedure because it allows you to run multiple server-side transactions. By using procedures in this way, we are able to break the problem down into a set of smaller transactions that cause less of a problem with database bloat and long-running transactions.

As an example, let's consider a case where we need to update all employees with the `A2` job grade, giving each person a 2% pay rise:

```
CREATE PROCEDURE annual_pay_rise (percent numeric)
LANGUAGE plpgsql AS $$
DECLARE
c CURSOR FOR
SELECT * FROM employee
    WHERE job_code = 'A2';
BEGIN
FOR r IN c LOOP
UPDATE employee
SET salary = salary * (1 + (percent/100.0))
WHERE empid = r.empid;
 IF mod (r.empid, 100) = 0 THEN
COMMIT;
END IF;
END LOOP;
END;
$$;
```

Execute the preceding procedure like this:

```
CALL annual_pay_rise(2);
```

We want to issue regular commits as we go. The preceding procedure is coded so that it issues commits roughly every 100 rows. There's nothing magical about that number; we just want to break it down into smaller pieces, whether it is the number of rows scanned or rows updated.

There's more...

You can use both `COMMIT` and `ROLLBACK` in a procedure. Each new transaction will see the changes from prior transactions and any other concurrent commits that have occurred.

What happens if your procedure is interrupted? Since we are using multiple transactions to complete the task, we won't expect the whole task to be atomic. If the execution is interrupted, we need to rerun the parts that didn't execute successfully. What happens if we accidentally rerun parts that have already been executed? We will give some people a double pay rise, but not everyone.

To cope, let's invent a simple job restart mechanism. This uses a persistent table to track changes as they are made, accessed by a simple API:

```
CREATE TABLE job_status
(id bigserial not null primary key,status text not null,restartdata bigint);
CREATE OR REPLACE FUNCTION job_start_new ()
 RETURNS bigint
 LANGUAGE plpgsql
 AS $$
 DECLARE
  p_id BIGINT;
BEGIN
  INSERT INTO job_status (status, restartdata)
     VALUES ('START', 0)
   RETURNING id INTO p_id;
  RETURN p_id;
 END; $$;
CREATE OR REPLACE FUNCTION job_get_status (jobid bigint)
RETURNS bigint
LANGUAGE plpgsql
AS $$
DECLARE
 rdata BIGINT;
BEGIN
  SELECT restartdata INTO rdata
    FROM job_status
    WHERE status != 'COMPLETE' AND id = jobid;
  IF NOT FOUND THEN
    RAISE EXCEPTION 'job id does not exist';
  END IF;
  RETURN rdata;
END; $$;
CREATE OR REPLACE PROCEDURE
job_update (jobid bigint, rdata bigint)
LANGUAGE plpgsql
AS $$
BEGIN
  UPDATE job_status
    SET status = 'IN PROGRESS'
```

```
       ,restartdata = rdata
    WHERE id = jobid;
END; $$;
CREATE OR REPLACE PROCEDURE job_complete (jobid bigint)
LANGUAGE plpgsql
AS $$
BEGIN
  UPDATE job_status SET status = 'COMPLETE'
    WHERE id = jobid;
END; $$;
```

First of all, we start a new job:

```
SELECT job_start_new();
```

Then, we execute our procedure, passing the job number to it. Let's say this returns `8474`:

```
CALL annual_pay_rise(8474);
```

If the procedure is interrupted, we will restart from the correct place, without needing to specify any changes:

```
CALL annual_pay_rise(8474);
```

The existing procedure needs to be modified to use the new restart API, as shown in the following code block. Note, also, that the cursor has to be modified to use an `ORDER BY` clause to make the procedure sensibly repeatable:

```
CREATE OR REPLACE PROCEDURE annual_pay_rise (job bigint)
LANGUAGE plpgsql AS $$
DECLARE
        job_empid bigint;
        c NO SCROLL CURSOR FOR
                SELECT * FROM employee
                WHERE job_code='A2'
                AND empid > job_empid
                ORDER BY empid;
BEGIN
        SELECT job_get_status(job) INTO job_empid;
        FOR r IN c LOOP
                UPDATE employee
                SET salary = salary * 1.02
                WHERE empid = r.empid;
                IF mod (r.empid, 100) = 0 THEN
                        CALL job_update(job, r.empid);
                        COMMIT;
                END IF;
        END LOOP;
        CALL job_complete(job);
END; $$;
```

For extra practice, follow the execution using the debugger in pgAdmin.

The `CALL` statement can also be used to call functions that return void, but other than that, functions and procedures are separate concepts. Procedures also allow you to execute transactions in PL/Python and PL/Perl.