R, Databases and Docker

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Contents

Chapter 1

Introduction

At the end of this chapter, you will be able to

- Understand the importance of using R and Docker to query a DBMS and access a service like Postgres outside of R.
- Setup your environment to explore the use-case for useRs.

1.1 Using R to query a DBMS in your organization

- Large data stores in organizations are stored in databases that have specific access constraints and structural characteristics. Data documentation may be incomplete, often emphasizes operational issues rather than analytic ones, and often needs to be confirmed on the fly. Data volumes and query performance are important design constraints.
- R users frequently need to make sense of complex data structures and coding schemes to address incompletely formed questions so that exploratory data analysis has to be fast. Exploratory techniques for the purpose should not be reinvented (and so would benefit from more public instruction or discussion).
- Learning to navigate the interfaces (passwords, packages, etc.) between R and a database is difficult to simulate outside corporate walls. Resources for interface problem diagnosis behind corporate walls may or may not address all the issues that R users face, so a simulated environment is needed.

1.2 Docker as a tool for UseRs

Noam Ross's "Docker for the UseR" suggests that there are four distinct Docker use-cases for useRs.

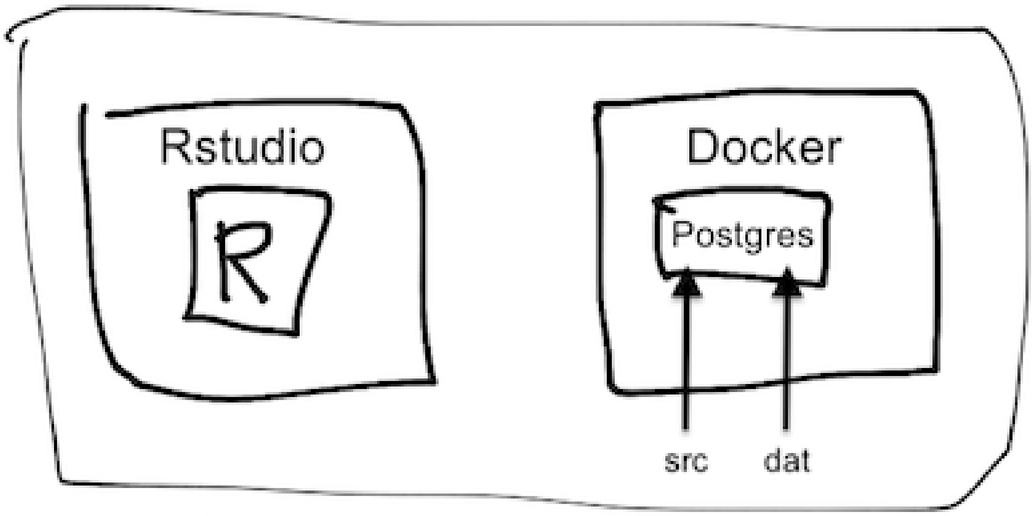
1. Make a fixed working environment for reproducible analysis
2. Access a service outside of R **(e.g., Postgres)**
3. Create an R based service (e.g., with `plumber`)
4. Send our compute jobs to the cloud with minimal reconfiguration or revision

This book explores #2 because it allows us to work on the database access issues described above and to practice on an industrial-scale DBMS.

- Docker is a relatively easy way to simulate the relationship between an R/RStudio session and a database – all on on a single machine, provided you have Docker installed and running.
- You may want to run PostgreSQL on a Docker container, avoiding any OS or system dependencies that might come up.

1.3 Docker and R on your machine

Here is how R and Docker fit on your operating system in this tutorial:



(This diagram needs to be updated as our directory structure evolves.)

1.4 Who are we?

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1.5 Prerequisites

You will need:

- A computer running Windows, MacOS, or Linux (Any Linux distro that will run Docker Community Edition, R and RStudio will work),
- R, and RStudio and
- Docker hosting.

The database we use is PostgreSQL 10, but you do not need to install that - it's installed via a Docker image. RStudio 1.2 is highly recommended but not required.

In addition to the current version of R and RStudio, you will need the following packages:

- tidyverse
- DBI
- RPostgres
- glue
- dbplyr

1.6 Install Docker

Install Docker. Installation depends on your operating system:

- On a Mac
- On UNIX flavors
- For Windows, consider these issues and follow these instructions.

1.7 Download the repo

First step: download this repo. It contains source code to build a Docker container that has the dvdrental database in PostgreSQL and shows how to interact with the database from R.

Chapter 2

Docker Hosting for Windows (02)

At the end of this chapter, you will be able to

- Setup your environment for Windows.
- Use Git and GitHub effectively on Windows.

Skip these instructions if your computer has either OSX or a Unix variant.

2.1 Hardware requirements

You will need an Intel or AMD processor with 64-bit hardware and the hardware virtualization feature. Most machines you buy today will have that, but older ones may not. You will need to go into the BIOS / firmware and enable the virtualization feature. You will need at least 4 gigabytes of RAM!

2.2 Software requirements

You will need Windows 7 64-bit or later. If you can afford it, I highly recommend upgrading to Windows 10 Pro.

2.2.1 Windows 7, 8, 8.1 and Windows 10 Home (64 bit)

Install Docker Toolbox. The instructions are here: https://docs.docker.com/toolbox/toolbox_install_windows/. Make sure you try the test cases and they work!

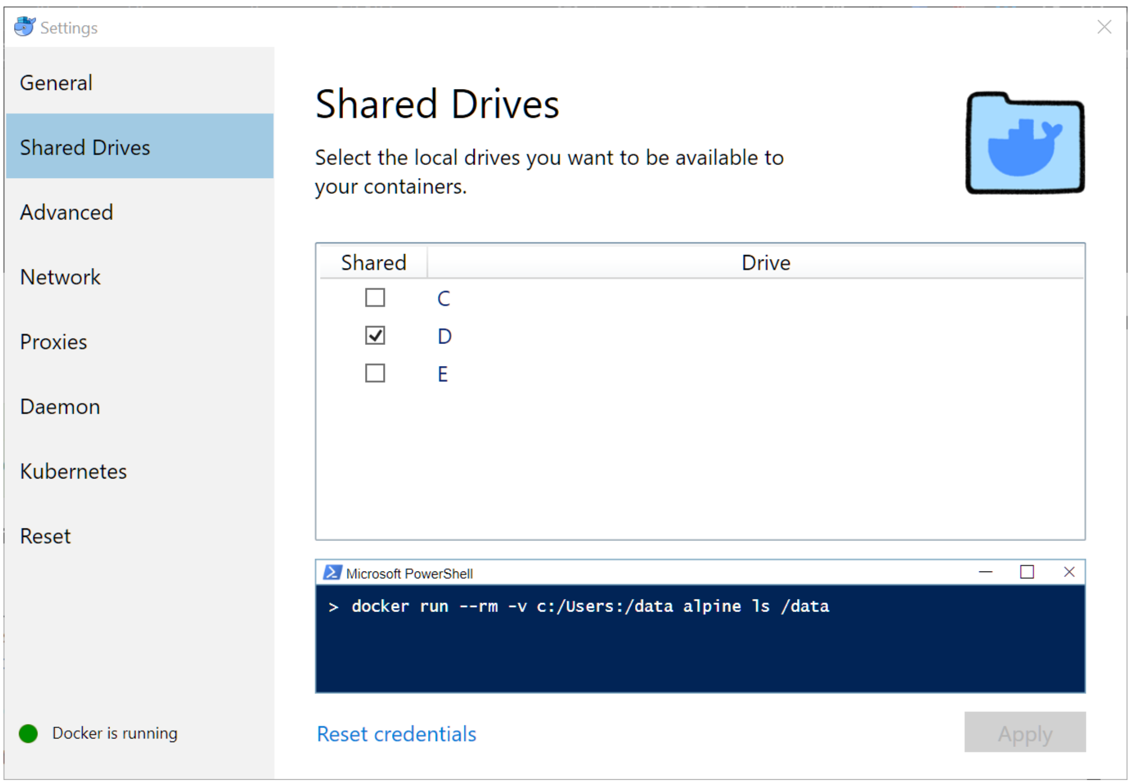
2.2.2 Windows 10 Pro

Install Docker for Windows *stable*. The instructions are here: https://docs.docker.com/docker-for-windows/install/#start-docker-for-windows. Again, make sure you try the test cases and they work.

2.3 Docker for Windows settings

2.3.1 Shared drives

If you're going to mount host files into container file systems (as we do in the following chapters), you need to set up shared drives. Open the Docker settings dialog and select `Shared Drives`. Check the drives you want to share. In this screenshot, the `D:` drive is my 1 terabyte hard drive.

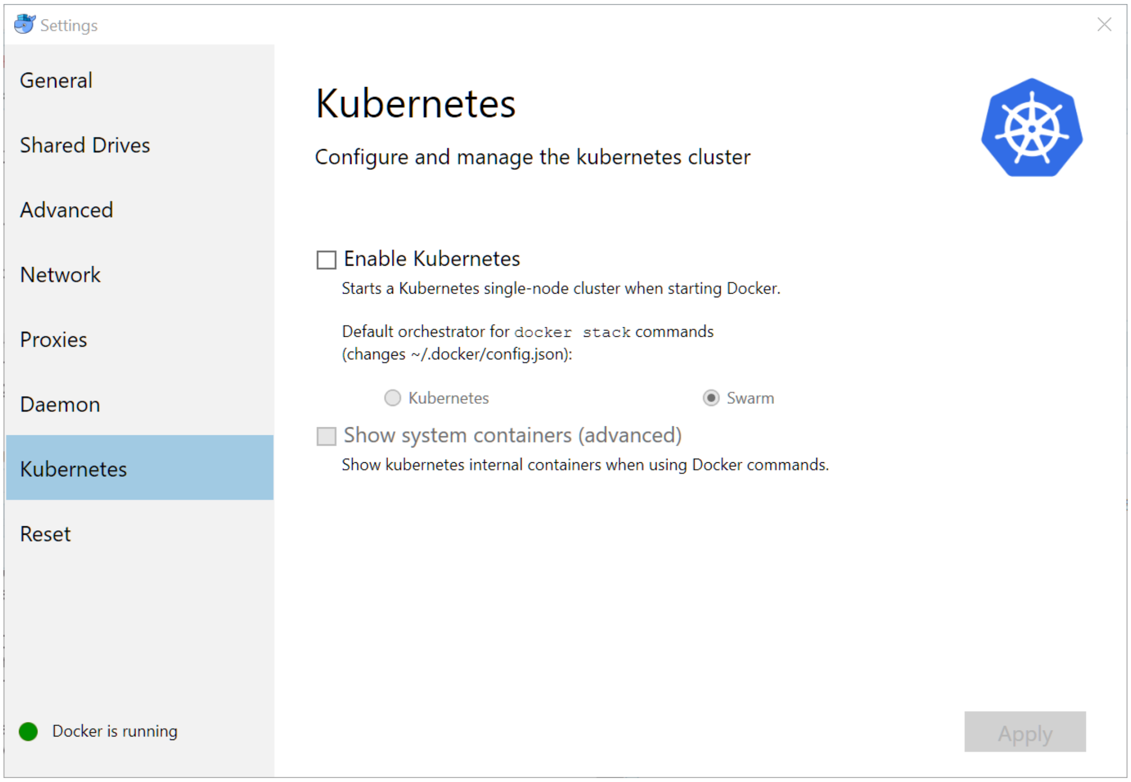


2.3.2 Kubernetes

Kubernetes is a container orchestration / cloud management package that's a major DevOps tool. It's heavily supported by Red Hat and Google, and as a result is becoming a required skill for DevOps.

However, it's overkill for this project at the moment. So you should make sure it's not enabled.

Go to the `Kubernetes` dialog and make sure the `Enable Kubernetes` checkbox is cleared.



2.4 Git, GitHub and line endings

Git was originally developed for Linux - in fact, it was created by Linus Torvalds to manage hundreds of different versions of the Linux kernel on different machines all around the world. As usage has grown, Git has achieved a huge following and is the version control system used by most large open source projects, including this one.

If you're on Windows, there are some things about Git and GitHub you need to watch. First of all, there are quite a few tools for running Git on Windows, but the RStudio default and recommended one is Git for Windows (https://git-scm.com/download/win).

By default, text files on Linux end with a single linefeed (`\n`) character. But on Windows, text files end with a carriage return and a line feed (`\r\n`). See https://en.wikipedia.org/wiki/Newline for the gory details.

Git defaults to checking files out in the native mode. So if you're on Linux, a text file will show up with the Linux convention, and if you're on Windows, it will show up with the Windows convention.

Most of the time this doesn't cause any problems. But Docker containers usually run Linux, and if you have files from a repository on Windows that you've sent to the container, the container may malfunction or give weird results. *This kind of situation has caused a lot of grief for contributors to this project, so beware.*

In particular, executable `sh` or `bash` scripts will fail in a Docker container if they have Windows line endings. You may see an error message with `\r` in it, which means the shell saw the carriage return (`\r`) and gave up. But often you'll see no hint at all what the problem was.

So you need a way to tell Git that some files need to be checked out with Linux line endings. See https://help.github.com/articles/dealing-with-line-endings/ for the details. Summary:

1. You'll need a `.gitattributes` file in the root of the repository.
2. In that file, all text files (scripts, program source, data, etc.) that are destined for a Docker container will need to have the designator `<spec> text eol=lf`, where `<spec>` is the file name specifier, for

example, `*.sh`.

This repo includes a sample: .gitattributes

Chapter 3

Learning Goals and Use Cases

At the end of this chapter, you will be able to

- Understand the importance of integrating R with databases using Docker.
- Understand the learning goals that you will have achieved by end of the tutorial.
- Learn the structure of the database and understand many use cases that can apply to you.

3.1 Context: Why integrate R with databases using Docker? (03)

- Large data stores in organizations are stored in databases that have specific access constraints and structural characteristics.
- Learning to navigate the gap between R and the database is difficult to simulate outside corporate walls.
- R users frequently need to make sense of complex data structures using diagnostic techniques that should not be reinvented (and so would benefit from more public instruction and commentary).
- Docker is a relatively easy way to simulate the relationship between an R/Rstudio session and database – all on on a single machine.

3.2 Learning Goals

After working through this tutorial, you can expect to be able to:

- Run queries against PostgreSQL in an environment that simulates what you will find in a corporate setting.
- Understand some of the trade-offs between:
    1. queries aimed at exploration or informal investigation using dplyr; and
    2. those where performance is important because of the size of the database or the frequency with which a query is run.
- Rewrite `dplyr` queries as SQL and submit them directly.
- Gain some understanding of techniques for assessing query structure and performance.
- Set up a PostgreSQL database in a Docker environment.
- Understand enough about Docker to swap databases, e.g. Sports DB for the DVD rental database used in this tutorial. Or swap the database management system (DBMS), e.g. MySQL for PostgreSQL.

3.3 Use cases

Imagine that you have one of several roles at our fictional company **DVDs R Us** and that you need to:

- As a data scientist, I want to know the distribution of number of rentals per month per customer, so that the Marketing department can create incentives for customers in 3 segments: Frequent Renters, Average Renters, Infrequent Renters.
- As the Director of Sales, I want to see the total number of rentals per month for the past 6 months and I want to know how fast our customer base is growing/shrinking per month for the past 6 months.
- As the Director of Marketing, I want to know which categories of DVDs are the least popular, so that I can create a campaign to draw attention to rarely used inventory.
- As a shipping clerk, I want to add rental information when I fulfill a shipment order.
- As the Director of Analytics, I want to test as much of the production R code in my shop as possible against a new release of the DBMS that the IT department is implementing next month.
- etc.

3.4 ERD Diagram

This tutorial uses the Postgres version of "dvd rental" database, which can be downloaded here. Here's a glimpse of it's structure:

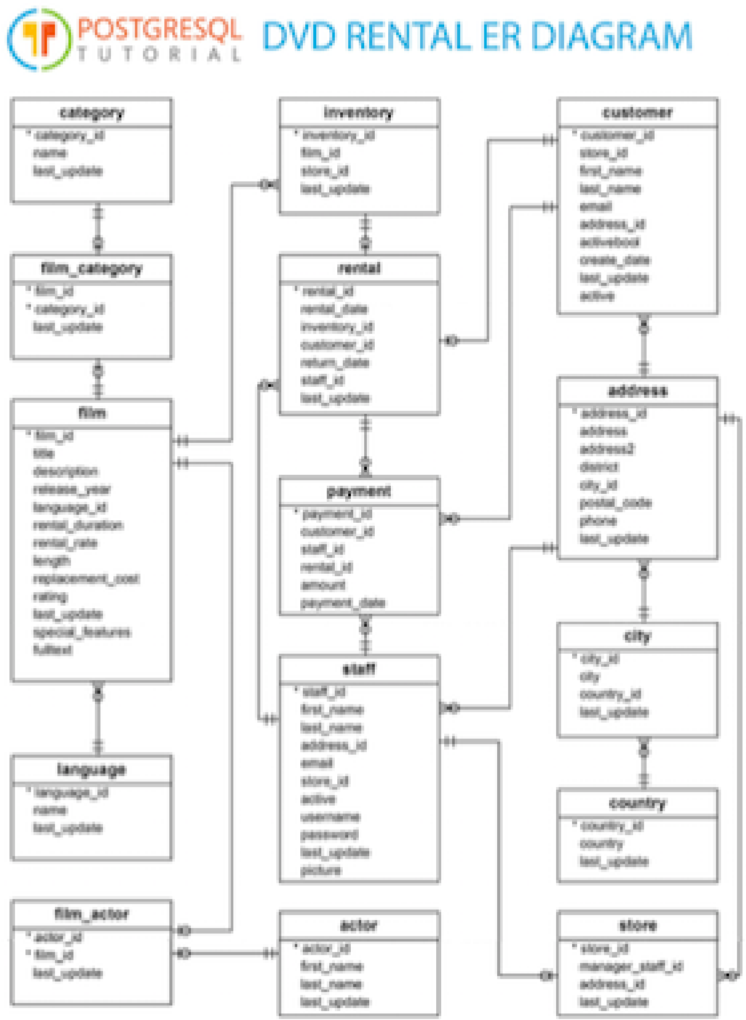


Figure 3.1: Entity Relationship diagram for the dvdrental database

Chapter 4

Docker, Postgres, and R (04)

At the end of this chapter, you will be able to

- Run, clean-up and close Docker containers.
- See how to keep credentials secret in code that's visible to the world.
- Interact with Postgres using Rstudio inside Docker container. # Read and write to postgreSQL from R.

We always load the tidyverse and some other packages, but don't show it unless we are using packages other than `tidyverse`, `DBI`, `RPostgres`, and `glue`.

4.1 Verify that Docker is running

Docker commands can be run from a terminal (e.g., the Rstudio Terminal pane) or with a `system()` command. In this tutorial, we use `system2()` so that all the output that is created externally is shown. Note that `system2` calls are divided into several parts:

1. The program that you are sending a command to.
2. The parameters or commands that are being sent.
3. `stdout = TRUE, stderr = TRUE` are two parameters that are standard in this book, so that the command's full output is shown in the book.

Check that docker is up and running:

```
sp_check_that_docker_is_up()
```

```
## [1] "Docker is up but running no containers"
```

4.2 Clean up if appropriate

Remove the `cattle` and `sql-pet` containers if they exists (e.g., from a prior experiments).

```
sp_docker_remove_container("cattle")
```

```
## Warning in system2("docker", docker_command, stdout = TRUE, stderr = TRUE):
## running command ''docker' rm cattle 2>&1' had status 1
```

```
## [1] "Error: No such container: cattle"
## attr(,"status")
## [1] 1
```

```
sp_docker_remove_container("sql-pet")
```

```
## [1] "sql-pet"
```

The convention we use in this book is to assemble a command with `glue` so that the you can see all of its separate parts. The following chunk just constructs the command, but does not execute it. If you have problems executing a command, you can always copy the command and execute in your terminal session.

```
docker_cmd <- glue(
  "run ",      # Run is the Docker command.  Everything that follows are `docker run` parameters.
  "--detach ", # (or `-d`) tells Docker to disconnect from the terminal / program issuing the command
  "--name cattle ",       # tells Docker to give the container a name: `cattle`
  "--publish 5432:5432 ", # tells Docker to expose the Postgres port 5432 to the local network with 543
  " postgres:10 "  # tells Docker the image that is to be run (after downloading if necessary)
)

# We name containers `cattle` for "throw-aways" and `pet` for ones we treasure and keep around.  :-)
```

Show and then submit the command constructed above:

```
cat(glue(" docker ", docker_cmd))
```

```
##  docker run --detach --name cattle --publish 5432:5432  postgres:10
```

```
# this is how R submits it to Docker:
system2("docker", docker_cmd, stdout = TRUE, stderr = TRUE)
```

```
## [1] "6947e87f060781532da2886ba18d5ac5eea6685825aa71605e8662d6f6675caf"
```

Docker returns a long string of numbers. If you are running this command for the first time, Docker downloads the PostgreSQL image, which takes a bit of time.

The following command shows that a container named `cattle` is running `postgres:10`. `postgres` is waiting for a connection:

```
sp_check_that_docker_is_up()
```

```
## [1] "Docker is up, running these containers:"
## [2] "CONTAINER ID      IMAGE          COMMAND               CREATED         STATUS             PORTS
## [3] "6947e87f0607      postgres:10      \"docker-entrypoint.s…\"   1 second ago      Up Less than a secon
```

4.3 Connect, read and write to Postgres from R

4.3.1 Pause for some security considerations

We use the following `sp_get_postgres_connection` function, which will repeatedly try to connect to PostgreSQL. PostgreSQL can take different amounts of time to come up and be ready to accept connections from R, depending on various factors that will be discussed later on.

This is how the `sp_get_postgres_connection` function is used:

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "postgres",
                         seconds_to_test = 10)
```

If you don't have an `.Rprofile` file that defines those passwords, you can just insert a string for the parameter, like:

```
password = 'whatever',
```

Make sure that you can connect to the PostgreSQL database that you started earlier. If you have been executing the code from this tutorial, the database will not contain any tables yet:

```r
dbListTables(con)
```

```
## character(0)
```

4.3.2 Alternative: put the database password in an environment file

The goal is to put the password in an untracked file that will **not** be committed in your source code repository. Your code can reference the name of the variable, but the value of that variable will not appear in open text in your source code.

We have chosen to call the file `dev_environment.csv` in the current working directory where you are executing this script. That file name appears in the `.gitignore` file, so that you will not accidentally commit it. We are going to create that file now.

You will be prompted for the database password. By default, a PostgreSQL database defines a database user named `postgres`, whose password is `postgres`. If you have changed the password or created a new user with a different password, then enter those new values when prompted. Otherwise, enter `postgres` and `postgres` at the two prompts.

In an interactive environment, you could execute a snippet of code that prompts the user for their username and password with the following snippet (which isn't run in the book):

Your password is still in plain text in the file, `dev_environment.csv`, so you should protect that file from exposure. However, you do not need to worry about committing that file accidentally to your git repository, because the name of the file appears in the `.gitignore` file.

For security, we use values from the `environment_variables` data.frame, rather than keeping the `username` and `password` in plain text in a source file.

4.3.3 Interact with Postgres

Write `mtcars` to PostgreSQL

```r
dbWriteTable(con, "mtcars", mtcars, overwrite = TRUE)
```

List the tables in the PostgreSQL database to show that `mtcars` is now there:

```r
dbListTables(con)
```

```
## [1] "mtcars"
```

```r
# list the fields in mtcars:
dbListFields(con, "mtcars")
```

```
##  [1] "mpg"  "cyl"  "disp" "hp"   "drat" "wt"   "qsec" "vs"   "am"   "gear"
## [11] "carb"
```

Download the table from the DBMS to a local data frame:

```r
mtcars_df <- tbl(con, "mtcars")

# Show a few rows:
knitr::kable(head(mtcars_df))
```

mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
18.1	6	225	105	2.76	3.460	20.22	1	0	3	1

4.4 Clean up

Afterwards, always disconnect from the DBMS, stop the docker container and (optionally) remove it.

```
dbDisconnect(con)

# tell Docker to stop the container:
sp_docker_stop("cattle")
```

```
## [1] "cattle"
```

```
# Tell Docker to remove the container from it's library of active containers:
sp_docker_remove_container("cattle")
```

```
## [1] "cattle"
```

If we `stop` the docker container but don't remove it (with the `rm cattle` command), the container will persist and we can start it up again later with `start cattle`. In that case, `mtcars` would still be there and we could retrieve it from R again. Since we have now removed the `cattle` container, the whole database has been deleted. (There are enough copies of `mtcars` in the world, so no great loss.)

Chapter 5

A persistent database in Postgres in Docker - all at once (05)

At the end of this chapter, you will be able to

- Setup a database with "all in one" approach.
- Stop and start Docker image to demonstrate persistence
- Disconnect R from database and stop container to close up even though it still exists.

5.1 Overview

You've already connected to PostgreSQL with R, now you need a "realistic" (`dvdrental`) database. We're going to demonstrate how to set one up, with two different approaches. This chapter and the next do the same job, illustrating the different approaches that you can take and helping you see the different points where you could swap what's provided here with a different DBMS or a different backup file or something else.

The code in this first version is recommended because it is an "all in one" approach. Details about how it works and how you might modify it are included below. There is another version in the the next chapter that you can use to investigate Docker commands and components.

Note that `tidyverse`, `DBI`, `RPostgres`, and `glue` are loaded.

5.2 Verify that Docker is up and running

```
system2("docker", "version", stdout = TRUE, stderr = TRUE)
```

```
##  [1] "Client:"
##  [2] " Version:           18.06.1-ce"
##  [3] " API version:       1.38"
##  [4] " Go version:        go1.10.3"
##  [5] " Git commit:        e68fc7a"
##  [6] " Built:             Tue Aug 21 17:21:31 2018"
##  [7] " OS/Arch:           darwin/amd64"
##  [8] " Experimental:      false"
##  [9] ""
## [10] "Server:"
```

```
## [11] " Engine:"
## [12] "  Version:          18.06.1-ce"
## [13] "  API version:      1.38 (minimum version 1.12)"
## [14] "  Go version:       go1.10.3"
## [15] "  Git commit:       e68fc7a"
## [16] "  Built:            Tue Aug 21 17:29:02 2018"
## [17] "  OS/Arch:          linux/amd64"
## [18] "  Experimental:     true"
```

5.3 Clean up if appropriate

Remove the `sql-pet` container if it exists (e.g., from a prior run)

```
if (system2("docker", "ps -a", stdout = TRUE) %>%
   grepl(x = ., pattern = 'sql-pet') %>%
   any()) {
     system2("docker", "rm -f sql-pet")
}
```

5.4 Build the Docker Image

Build an image that derives from postgres:10, defined in `dvdrental.Dockerfile`, that is set up to restore and load the dvdrental db on startup. The dvdrental.Dockerfile is discussed below.

```
system2("docker",
        glue("build ", # tells Docker to build an image that can be loaded as a container
          "--tag postgres-dvdrental ", # (or -t) tells Docker to name the image
          "--file dvdrental.Dockerfile ", #(or -f) tells Docker to read `build` instructions from the d
          " . "),  # tells Docker to look for dvdrental.Dockerfile in the current directory
          stdout = TRUE, stderr = TRUE)
```

```
##  [1] "Sending build context to Docker daemon  23.84MB\r\r"
##  [2] "Step 1/4 : FROM postgres:10"
##  [3] " ---> ac25c2bac3c4"
##  [4] "Step 2/4 : WORKDIR /tmp"
##  [5] " ---> Using cache"
##  [6] " ---> 3f00a18e0bdf"
##  [7] "Step 3/4 : COPY init-dvdrental.sh /docker-entrypoint-initdb.d/"
##  [8] " ---> Using cache"
##  [9] " ---> 3453d61d8e3e"
## [10] "Step 4/4 : RUN apt-get -qq update &&  apt-get install -y -qq curl zip  > /dev/null 2>&1 &&  curl -Os
## [11] " ---> Using cache"
## [12] " ---> f5e93aa64875"
## [13] "Successfully built f5e93aa64875"
## [14] "Successfully tagged postgres-dvdrental:latest"
```

5.5 Run the Docker Image

Run docker to bring up postgres. The first time it runs it will take a minute to create the PostgreSQL environment. There are two important parts to this that may not be obvious:

- The `source=` parameter points to dvdrental.Dockerfile, which does most of the heavy lifting. It has detailed, line-by-line comments to explain what it is doing.

- *Inside* dvdrental.Dockerfile the command `COPY init-dvdrental.sh /docker-entrypoint-initdb.d/` copies init-dvdrental.sh from the local file system into the specified location in the Docker container. When the PostgreSQL Docker container initializes, it looks for that file and executes it.

Doing all of that work behind the scenes involves two layers of complexity. Depending on how you look at it, that may be more or less difficult to understand than the method shown in the next Chapter.

```
wd <- getwd()

docker_cmd <- glue(
  "run ",      # Run is the Docker command.  Everything that follows are `run` parameters.
  "--detach ", # (or `-d`) tells Docker to disconnect from the terminal / program issuing the command
  " --name sql-pet ",     # tells Docker to give the container a name: `sql-pet`
  "--publish 5432:5432 ", # tells Docker to expose the Postgres port 5432 to the local network with 543
  "--mount ", # tells Docker to mount a volume -- mapping Docker's internal file structure to the host
  "type=bind,", # tells Docker that the mount command points to an actual file on the host system
  'source="', # tells Docker where the local file will be found
  wd, '/",', # the current working directory, as retrieved above
  "target=/petdir", # tells Docker to refer to the current directory as "/petdir" in its file system
  " postgres-dvdrental" # tells Docker to run the image was built in the previous step
)

# if you are curious you can paste this string into a terminal window after the command 'docker':
docker_cmd
```

```
## run --detach  --name sql-pet --publish 5432:5432 --mount type=bind,source="/Users/jds/Documents/Library/
```

```
system2("docker", docker_cmd, stdout = TRUE, stderr = TRUE)
```

```
## [1] "6bfa0eb3778db02f27a9a86ee2b1dd1d6b2f4560511be2b209e4f5247e17af52"
```

5.6 Connect to Postgres with R

Use the DBI package to connect to PostgreSQL. But first, wait for Docker & PostgreSQL to come up before connecting.

We have loaded the `wait_for_postgres` function behind the scenes.

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)

dbListTables(con)
```

```
##  [1] "actor_info"                 "customer_list"
##  [3] "film_list"                  "nicer_but_slower_film_list"
##  [5] "sales_by_film_category"     "staff"
##  [7] "sales_by_store"             "staff_list"
##  [9] "category"                   "film_category"
## [11] "country"                    "actor"
## [13] "language"                   "inventory"
## [15] "payment"                    "rental"
```

```
## [17] "city"                        "store"
## [19] "film"                        "address"
## [21] "film_actor"                  "customer"
```

```
dbListFields(con, "rental")
```

```
## [1] "rental_id"    "rental_date"  "inventory_id" "customer_id"
## [5] "return_date"  "staff_id"     "last_update"
```

```
dbDisconnect(con)
```

5.7 Stop and start to demonstrate persistence

Stop the container

```
sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Restart the container and verify that the dvdrental tables are still there

```
sp_docker_start("sql-pet")

con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)

glimpse(dbReadTable(con, "film"))
```

```
## Observations: 1,000
## Variables: 13
## $ film_id          <int> 133, 384, 8, 98, 1, 2, 3, 4, 5, 6, 7, 9, 10, ...
## $ title            <chr> "Chamber Italian", "Grosse Wonderful", "Airpo...
## $ description      <chr> "A Fateful Reflection of a Moose And a Husban...
## $ release_year     <int> 2006, 2006, 2006, 2006, 2006, 2006, 2006, 200...
## $ language_id      <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ rental_duration  <int> 7, 5, 6, 4, 6, 3, 7, 5, 6, 3, 6, 3, 6, 6, 6, ...
## $ rental_rate      <dbl> 4.99, 4.99, 4.99, 4.99, 0.99, 4.99, 2.99, 2.9...
## $ length           <int> 117, 49, 54, 73, 86, 48, 50, 117, 130, 169, 6...
## $ replacement_cost <dbl> 14.99, 19.99, 15.99, 12.99, 20.99, 12.99, 18....
## $ rating           <chr> "NC-17", "R", "R", "PG-13", "PG", "G", "NC-17...
## $ last_update      <dttm> 2013-05-26 14:50:58, 2013-05-26 14:50:58, 20...
## $ special_features <chr> "{Trailers}", "{\"Behind the Scenes\"}", "{Tr...
## $ fulltext         <chr> "'chamber':1 'fate':4 'husband':11 'italian':...
```

5.8 Cleaning up

It's always good to have R disconnect from the database

```
dbDisconnect(con)
```

Stop the container and show that the container is still there, so can be started again.

```
sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

```
# show that the container still exists even though it's not running
sp_show_all_docker_containers()
```

```
## [1] "CONTAINER ID      IMAGE             COMMAND                  CREATED          STATUS                     POR
## [2] "6bfa0eb3778d      postgres-dvdrental   \"docker-entrypoint.s…\"   8 seconds ago     Exited (0) Less t
```

Next time, you can just use this command to start the container:

```
sp_docker_start("sql-pet")
```

And once stopped, the container can be removed with:

```
sp_check_that_docker_is_up("sql-pet)
```

5.9 Using the `sql-pet` container in the rest of the book

After this point in the book, we assume that Docker is up and that we can always start up our *sql-pet database* with:

```
sp_docker_stop("sql-pet")
```

Chapter 6

Introduction: Postgres queries from R (10)

Note that `tidyverse`, `DBI`, `RPostgres`, `glue`, and `knitr` are loaded. Also, we've sourced the `[db-login-batch-code.R]('r-database-docker/book-src/db-login-batch-code.R')` file which is used to log in to PostgreSQL.

6.1 Basics

- Keeping passwords secure.
- Coverage in this book. There are many SQL tutorials that are available. For example, we are drawing some materials from a tutorial we recommend. In particular, we will not replicate the lessons there, which you might want to complete. Instead, we are showing strategies that are recommended for R users. That will include some translations of queries that are discussed there.

6.2 Ask yourself, what are you aiming for?

- Differences between production and data warehouse environments.
- Learning to keep your DBAs happy:
  - You are your own DBA in this simulation, so you can wreak havoc and learn from it, but you can learn to be DBA-friendly here.
  - In the end it's the subject-matter experts that understand your data, but you have to work with your DBAs first.

6.3 Get some basic information about your database

Assume that the Docker container with PostgreSQL and the dvdrental database are ready to go.

```
sp_docker_start("sql-pet")

con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)
```

Chapter 7

Simple queries (11)

Assume that the Docker container with PostgreSQL and the dvdrental database are ready to go.

```
sp_docker_start("sql-pet")
```

Connect to the database:

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)
```

7.1 Some extra handy libraries

https://dbplyr.tidyverse.org/articles/sql-translation.html

Here are some packages that we find handy in the preliminary investigation of a database (or a problem that involves data from a database).

```
library(glue)
library(skimr)
```

```
##
## Attaching package: 'skimr'

## The following object is masked from 'package:knitr':
##
##     kable
```

7.2 Basic investigation

- Need both familiarity with the data and a focus question
  - An interative process
  - Each informs the other
- R tools for data investigation
  - glimpse
  - str
  - View and kable
- overview investigation: do you understand your data

    - documentation and its limits
    - what's *missing* from the database: (columns, records, cells)
- find out how the data is used by those who enter it and others who've used it before
    - why is there missing data?

7.3 Using `dplyr`

We already started, but that's OK.

7.3.1 Finding out what's in the database

- DBI / RPostgres packages
- R tools like glimpse, skimr, kable.
- Tutorials like: https://suzan.rbind.io/tags/dplyr/
- Benjamin S. Baumer, A Grammar for Reproducible and Painless Extract-Transform-Load Operations on Medium Data: https://arxiv.org/pdf/1708.07073

7.3.2 Sample query

- rental
- date subset

7.3.3 Subset: only retrieve what you need

- Columns
- Rows
    - number of row
    - specific rows
- Counts & stats

7.3.4 Make the server do as much work as you can

discuss this simple example? http://www.postgresqltutorial.com/postgresql-left-join/

- `dplyr` joins on the server side
- Where you put `(collect(n = Inf))` really matters

7.4 What is `dplyr` sending to the server?

- show_query as a first draft

7.5 Writing SQL queries directly to the DBMS

- dbquery
- Glue for constructing SQL statements
    - parameterizing SQL queries

7.6 Choosing between `dplyr` and native SQL

- performance considerations: first get the right data, then worry about performance
- Trade offs between leaving the data in PostgreSQL vs what's kept in R:
  - browsing the data
  - larger samples and complete tables
  - using what you know to write efficient queries that do most of the work on the server

---

- left join staff
- left join customer
- dplyr joins in the R

```
sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Chapter 8

Leftovers (12)

Most of the content in this file has been moved elsewhere.

8.1 Some extra handy libraries

Here are some packages that we find handy in the preliminary investigation of a database (or a problem that involves data from a database).

```
library(glue)
library(skimr)
```

```
##
## Attaching package: 'skimr'
## The following object is masked from 'package:knitr':
##
##     kable
```

8.2 More topics

- Check this against Aaron Makubuya's workshop at the Cascadia R Conf.

8.3 Standards for production jobs

- writing tests for your queries

Chapter 9

Joins and complex queries (13)

9.1 Verify Docker is up and running:

```
result <- system2("docker", "version", stdout = TRUE, stderr = TRUE)
result
```

```
##  [1] "Client:"
##  [2] " Version:           18.06.1-ce"
##  [3] " API version:       1.38"
##  [4] " Go version:        go1.10.3"
##  [5] " Git commit:        e68fc7a"
##  [6] " Built:             Tue Aug 21 17:21:31 2018"
##  [7] " OS/Arch:           darwin/amd64"
##  [8] " Experimental:      false"
##  [9] ""
## [10] "Server:"
## [11] " Engine:"
## [12] "  Version:          18.06.1-ce"
## [13] "  API version:      1.38 (minimum version 1.12)"
## [14] "  Go version:       go1.10.3"
## [15] "  Git commit:       e68fc7a"
## [16] "  Built:            Tue Aug 21 17:29:02 2018"
## [17] "  OS/Arch:          linux/amd64"
## [18] "  Experimental:     true"
```

verify pet DB is available, it may be stopped.

```
result <- system2("docker", "ps -a", stdout = TRUE, stderr = TRUE)
result
```

```
## [1] "CONTAINER ID      IMAGE             COMMAND                CREATED          STATUS                    PORTS
## [2] "6bfa0eb3778d      postgres-dvdrental  \"docker-entrypoint.s…\"  26 seconds ago     Exited (137) 3 se
```

```
any(grepl('Up .+pet$',result))
```

```
## [1] FALSE
```

Start up the `docker-pet` container

```
sp_docker_start("sql-pet")
```

now connect to the database with R

```
# need to wait for Docker & Postgres to come up before connecting.

con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)
```

```
## select examples
##    dbGetQuery returns the entire result set as a data frame.
##        For large returned datasets, complex or inefficient SQL statements, this may take a
##        long time.

##      dbSendQuery: parses, compiles, creates the optimized execution plan.
##          dbFetch: Execute optimzed execution plan and return the dataset.
##    dbClearResult:remove pending query results from the database to your R environment
```

How many customers are there in the DVD Rental System

```
rs1 <- dbGetQuery(con,'select * from customer;')
kable(head(rs1))
```

customer_id	store_id	first_name	last_name	email	address_id	activebool	crea
524	1	Jared	Ely	jared.ely@sakilacustomer.org	530	TRUE	200
1	1	Mary	Smith	mary.smith@sakilacustomer.org	5	TRUE	200
2	1	Patricia	Johnson	patricia.johnson@sakilacustomer.org	6	TRUE	200
3	1	Linda	Williams	linda.williams@sakilacustomer.org	7	TRUE	200
4	2	Barbara	Jones	barbara.jones@sakilacustomer.org	8	TRUE	200
5	1	Elizabeth	Brown	elizabeth.brown@sakilacustomer.org	9	TRUE	200

```
pco <- dbSendQuery(con,'select * from customer;')
rs2  <- dbFetch(pco)
dbClearResult(pco)
kable(head(rs2))
```

customer_id	store_id	first_name	last_name	email	address_id	activebool	crea
524	1	Jared	Ely	jared.ely@sakilacustomer.org	530	TRUE	200
1	1	Mary	Smith	mary.smith@sakilacustomer.org	5	TRUE	200
2	1	Patricia	Johnson	patricia.johnson@sakilacustomer.org	6	TRUE	200
3	1	Linda	Williams	linda.williams@sakilacustomer.org	7	TRUE	200
4	2	Barbara	Jones	barbara.jones@sakilacustomer.org	8	TRUE	200
5	1	Elizabeth	Brown	elizabeth.brown@sakilacustomer.org	9	TRUE	200

```
# insert yourself as a new customer
dbExecute(con
         ,"insert into customer
                 (store_id,first_name,last_name,email,address_id
                 ,activebool,create_date,last_update,active)
           values(2,'Sophie','Yang','dodreamdo@yahoo.com',1,TRUE,'2018-09-13','2018-09-13',1)
          "
         )
```

```
## [1] 0
```

```
## anti join -- Find customers who have never rented a movie.

rs <- dbGetQuery(con,
                 "select c.first_name
                        ,c.last_name
```

```
                      ,c.email
                  from customer c
                       left outer join rental r
                            on c.customer_id = r.customer_id
                 where r.rental_id is null;
               "
               )
head(rs)
```

```
##   first_name last_name                email
## 1     Sophie      Yang dodreamdo@yahoo.com
```

```
## how many films and languages exist in the DVD rental application
rs <- dbGetQuery(con,
                "      select 'film' table_name,count(*) count from film
                 union select 'language' table_name,count(*) count from language
               ;
                "
                )
head(rs)
```

```
##   table_name count
## 1       film  1000
## 2   language     6
```

```
## what is the film distribution based on language

rs <- dbGetQuery(con,
                "select l.language_id id
                       ,l.name
                       ,sum(case when f.language_id is not null then 1 else 0 end) total
                   from language l
                        full outer join film f
                             on l.language_id = f.language_id
                  group by l.language_id,l.name
                  order by l.name;
                 ;
                "
                )
head(rs)
```

```
##   id                 name total
## 1  1 English              1000
## 2  5 French                  0
## 3  6 German                  0
## 4  2 Italian                 0
## 5  3 Japanese                0
## 6  4 Mandarin                0
```

```
## Store analysis
### which store has had more rentals and income
rs <- dbGetQuery(con,
                "select *
                 from (      select 'actor' tbl_name,count(*) from actor
                       union select 'category' tbl_name,count(*) from category
                       union select 'film' tbl_name,count(*) from film
```

```
                     union select 'film_actor' tbl_name,count(*) from film_actor
                     union select 'film_category' tbl_name,count(*) from film_category
                     union select 'language' tbl_name,count(*) from language
                     union select 'inventory' tbl_name,count(*) from inventory
                     union select 'rental' tbl_name,count(*) from rental
                     union select 'payment' tbl_name,count(*) from payment
                     union select 'staff' tbl_name,count(*) from staff
                     union select 'customer' tbl_name,count(*) from customer
                     union select 'address' tbl_name,count(*) from address
                     union select 'city' tbl_name,count(*) from city
                     union select 'country' tbl_name,count(*) from country
                     union select 'store' tbl_name,count(*) from store
                     ) counts
                order by tbl_name
               ;
              "
              )
head(rs)
```

```
##   tbl_name count
## 1    actor   200
## 2  address   603
## 3 category    16
## 4     city   600
## 5  country   109
## 6 customer   600
```

```
## Store analysis
### which store has the largest income stream
rs <- dbGetQuery(con,
                "select store_id,sum(amount) amt,count(*) cnt
                   from payment p
                        join staff s
                          on p.staff_id = s.staff_id
                 group by store_id order by 2 desc
                 ;
                "
                )
head(rs)
```

```
##   store_id      amt  cnt
## 1        2 31059.92 7304
## 2        1 30252.12 7292
```

```
## Store analysis
### How many rentals have not been paid
### How many rentals have been paid
### How much has been paid
### What is the average price/movie
### Estimate the outstanding balance
rs <- dbGetQuery(con,
                "select sum(case when payment_id is null then 1 else 0 end) missing
                       ,sum(case when payment_id is not null then 1 else 0 end) found
                       ,sum(p.amount) amt
                       ,count(*) cnt
```

```
                       ,round(sum(p.amount)/sum(case when payment_id is not null then 1 else 0 end),2) a
                       ,round(round(sum(p.amount)/sum(case when payment_id is not null then 1 else 0 end
                                  * sum(case when payment_id is null then 1 else 0 end),2) est_balance
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                ;
                "
                )
head(rs)
```

```
##   missing found      amt   cnt avg_price est_balance
## 1    1452 14596 61312.04 16048       4.2      6098.4
```

```
### what is the actual outstanding balance

rs <- dbGetQuery(con,
                "select sum(f.rental_rate) open_amt,count(*) count
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                  where p.rental_id is null
                 ;"
                )
head(rs)
```

```
##   open_amt count
## 1  4297.48  1452
```

```
### Rank customers with highest open amounts

rs <- dbGetQuery(con,
                "select c.customer_id,c.first_name,c.last_name,sum(f.rental_rate) open_amt,count(*) cou
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                        join customer c
                          on r.customer_id = c.customer_id
                  where p.rental_id is null
                  group by c.customer_id,c.first_name,c.last_name
                  order by open_amt desc
                  limit 25
                 ;"
                )
head(rs)
```

```
##   customer_id first_name last_name open_amt count
## 1         293        Mae  Fletcher    35.90    10
```

```
## 2         307     Joseph       Joy    31.90    10
## 3         316     Steven    Curley    31.90    10
## 4         299      James    Gannon    30.91     9
## 5         274      Naomi  Jennings    29.92     8
## 6         326       Jose    Andrew    28.93     7
```

```
### what film has been rented the most
rs <- dbGetQuery(con,
                "select i.film_id,f.title,rental_rate,sum(rental_rate) revenue,count(*) count  --16044
                   from rental r
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                 group by i.film_id,f.title,rental_rate
                 order by count desc
                 ;"
                )
head(rs)
```

```
##   film_id               title rental_rate revenue count
## 1     103  Bucket Brotherhood        4.99  169.66    34
## 2     738    Rocketeer Mother        0.99   32.67    33
## 3     382      Grit Clockwork        0.99   31.68    32
## 4     767       Scalawag Duck        4.99  159.68    32
## 5     489      Juggler Hardly        0.99   31.68    32
## 6     730 Ridgemont Submarine        0.99   31.68    32
```

```
### what film has been generated the most revenue assuming all amounts are collected
rs <- dbGetQuery(con,
                "select i.film_id,f.title,rental_rate
                       ,sum(rental_rate) revenue,count(*) count  --16044
                   from rental r
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                 group by i.film_id,f.title,rental_rate
                 order by revenue desc
                 ;"
                )
head(rs)
```

```
##   film_id              title rental_rate revenue count
## 1     103 Bucket Brotherhood        4.99  169.66    34
## 2     767      Scalawag Duck        4.99  159.68    32
## 3     973          Wife Turn        4.99  154.69    31
## 4      31      Apache Divine        4.99  154.69    31
## 5     369  Goodfellas Salute        4.99  154.69    31
## 6    1000          Zorro Ark        4.99  154.69    31
```

```
### which films are in one store but not the other.
rs <- dbGetQuery(con,
                "select coalesce(i1.film_id,i2.film_id) film_id
                       ,f.title,f.rental_rate,i1.store_id,i1.count,i2.store_id,i2.count
                   from     (select film_id,store_id,count(*) count
```

```
                              from inventory where store_id = 1
                            group by film_id,store_id) as i1
                        full outer join
                           (select film_id,store_id,count(*) count
                              from inventory where store_id = 2
                            group by film_id,store_id
                           ) as i2
                          on i1.film_id = i2.film_id
                        join film f
                          on coalesce(i1.film_id,i2.film_id) = f.film_id
                 where i1.film_id is null or i2.film_id is null
                order by f.title  ;
              "
               )
head(rs)
```

```
##   film_id               title rental_rate store_id count store_id..6
## 1       2      Ace Goldfinger        4.99       NA  <NA>           2
## 2       3    Adaptation Holes        2.99       NA  <NA>           2
## 3       5         African Egg        2.99       NA  <NA>           2
## 4       8     Airport Pollock        4.99       NA  <NA>           2
## 5      13         Ali Forever        4.99       NA  <NA>           2
## 6      20 Amelie Hellfighters        4.99        1     3          NA
##   count..7
## 1        3
## 2        4
## 3        3
## 4        4
## 5        4
## 6     <NA>
```

```
# Compute the outstanding balance.
rs <- dbGetQuery(con,
                "select sum(f.rental_rate) open_amt,count(*) count
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                  where p.rental_id is null
                 ;"
                )
head(rs)
```

```
##   open_amt count
## 1  4297.48  1452
```

list what's there

```
dbListTables(con)
```

```
##  [1] "actor_info"                 "customer_list"
##  [3] "film_list"                  "nicer_but_slower_film_list"
##  [5] "sales_by_film_category"     "staff"
```

```
##  [7] "sales_by_store"             "staff_list"
##  [9] "category"                   "film_category"
## [11] "country"                    "actor"
## [13] "language"                   "inventory"
## [15] "payment"                    "rental"
## [17] "city"                       "store"
## [19] "film"                       "address"
## [21] "film_actor"                 "customer"
```

Clean up

```
# dbRemoveTable(con, "cars")
# dbRemoveTable(con, "mtcars")
# dbRemoveTable(con, "cust_movies")

# diconnect from the db
dbDisconnect(con)

result <- system2("docker", "stop sql-pet", stdout = TRUE, stderr = TRUE)
result
```

```
## [1] "sql-pet"
```

Chapter 10

Postgres Examples, part B (14)

10.1 Verify Docker is up and running:

```
result <- system2("docker", "version", stdout = TRUE, stderr = TRUE)
result
```

```
##  [1] "Client:"
##  [2] " Version:           18.06.1-ce"
##  [3] " API version:       1.38"
##  [4] " Go version:        go1.10.3"
##  [5] " Git commit:        e68fc7a"
##  [6] " Built:             Tue Aug 21 17:21:31 2018"
##  [7] " OS/Arch:           darwin/amd64"
##  [8] " Experimental:      false"
##  [9] ""
## [10] "Server:"
## [11] " Engine:"
## [12] "  Version:          18.06.1-ce"
## [13] "  API version:      1.38 (minimum version 1.12)"
## [14] "  Go version:       go1.10.3"
## [15] "  Git commit:       e68fc7a"
## [16] "  Built:            Tue Aug 21 17:29:02 2018"
## [17] "  OS/Arch:          linux/amd64"
## [18] "  Experimental:     true"
```

verify pet DB is available, it may be stopped.

```
result <- system2("docker", "ps -a", stdout = TRUE, stderr = TRUE)
result
```

```
## [1] "CONTAINER ID      IMAGE            COMMAND              CREATED          STATUS              PORTS
## [2] "6bfa0eb3778d      postgres-dvdrental  \"docker-entrypoint.s…\"  31 seconds ago     Exited (0) 2 sec
```

```
any(grepl('Up .+pet$',result))
```

```
## [1] FALSE
```

Start up the `docker-pet` container

```
sp_docker_start("sql-pet")
```

now connect to the database with R

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                          password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                          dbname = "dvdrental",
                          seconds_to_test = 10)
```

All of the material from this file has moved to files 71, 72, and 73.

Clean up

```
# dbRemoveTable(con, "cars")
# dbRemoveTable(con, "mtcars")
# dbRemoveTable(con, "cust_movies")

# diconnect from the db
dbDisconnect(con)

sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Chapter 11

Getting metadata about and from the database (21)

Note that `tidyverse`, `DBI`, `RPostgres`, `glue`, and `knitr` are loaded. Also, we've sourced the `db-login-batch-code.R` file which is used to log in to PostgreSQL.

Assume that the Docker container with PostgreSQL and the dvdrental database are ready to go.

```
sp_docker_start("sql-pet")
```

Connect to the database:

```
con <-  sp_get_postgres_connection(
  user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
  password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
  dbname = "dvdrental",
  seconds_to_test = 10
)
```

11.1 Always *look* at the data

11.1.1 Connect with people who own, generate, or are the subjects of the data

A good chat with people who own the data, generate it, or are the subjects can generate insights and set the context for your investigation of the database. The purpose for collecting the data or circumsances where it was collected may be burried far afield in an organization, but *usually someone knows*. The metadata discussed in this chapter is essential but will only take you so far.

11.1.2 Browse a few rows of a table

Simple tools like `head` or `glimpse` are your friend.

```
rental <- dplyr::tbl(con, "rental")

kable(head(rental))
```

rental_id	rental_date	inventory_id	customer_id	return_date	staff_id	last_update
2	2005-05-24 22:54:33	1525	459	2005-05-28 19:40:33	1	2006-02-16 02:30:53
3	2005-05-24 23:03:39	1711	408	2005-06-01 22:12:39	1	2006-02-16 02:30:53
4	2005-05-24 23:04:41	2452	333	2005-06-03 01:43:41	2	2006-02-16 02:30:53
5	2005-05-24 23:05:21	2079	222	2005-06-02 04:33:21	1	2006-02-16 02:30:53
6	2005-05-24 23:08:07	2792	549	2005-05-27 01:32:07	1	2006-02-16 02:30:53
7	2005-05-24 23:11:53	3995	269	2005-05-29 20:34:53	2	2006-02-16 02:30:53

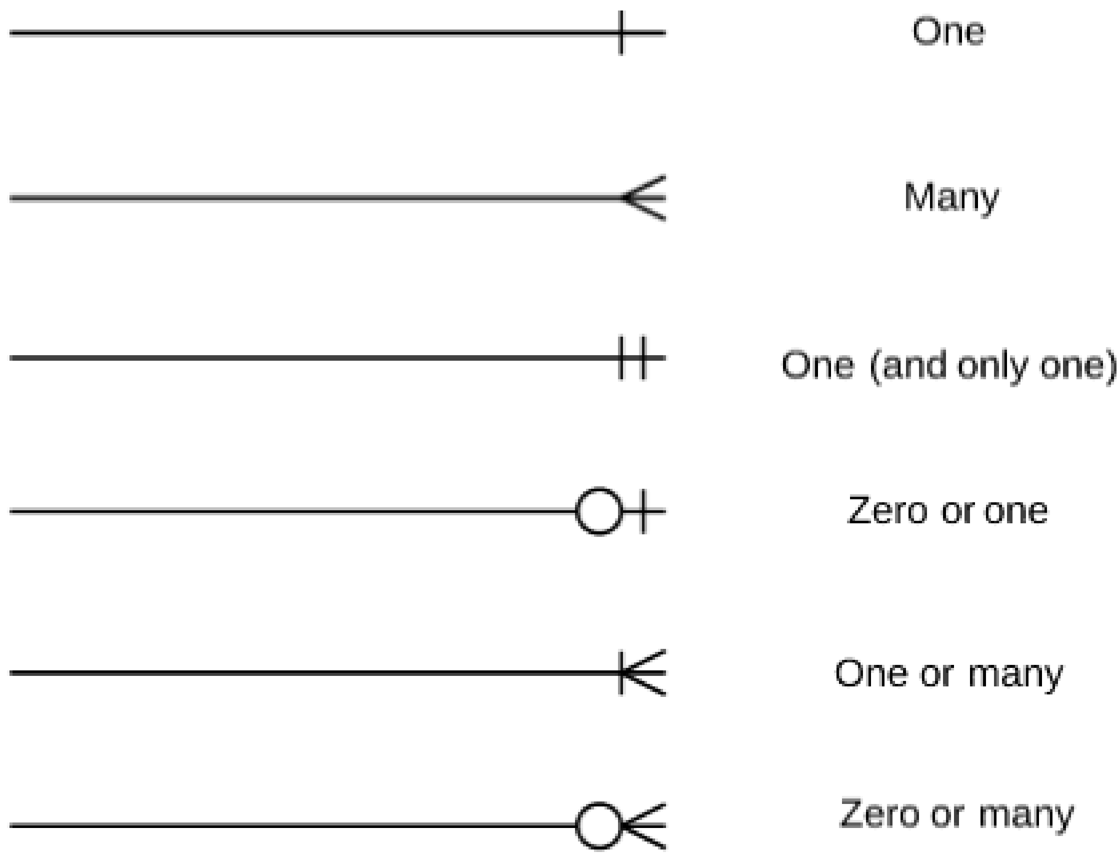
```r
glimpse(rental)
```

```
## Observations: ??
## Variables: 7
## $ rental_id    <int> 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 1...
## $ rental_date  <dttm> 2005-05-24 22:54:33, 2005-05-24 23:03:39, 2005-0...
## $ inventory_id <int> 1525, 1711, 2452, 2079, 2792, 3995, 2346, 2580, 1...
## $ customer_id  <int> 459, 408, 333, 222, 549, 269, 239, 126, 399, 142,...
## $ return_date  <dttm> 2005-05-28 19:40:33, 2005-06-01 22:12:39, 2005-0...
## $ staff_id     <int> 1, 1, 2, 1, 1, 2, 2, 1, 2, 2, 2, 1, 1, 1, 2, 1, 2...
## $ last_update  <dttm> 2006-02-16 02:30:53, 2006-02-16 02:30:53, 2006-0...
```

11.2 Database contents and structure

11.2.1 Database structure

For large or complex databases, however, you need to use both the available documentation for your database (e.g., the dvdrental database) and the other empirical tools that are available. For example it's worth learning to interpret the symbols in an Entity Relationship Diagram:



The `information_schema` is a trove of information *about* the database. Its format is more or less consistent across the different SQL implementations that are available. Here we explore some of what's available using several different methods. Postgres stores a lot of metadata.

11.2.2 Contents of the `information_schema`

For this chapter R needs the `dbplyr` package to access alternate schemas. A schema is an object that contains one or more tables. Most often there will be a default schema, but to access the metadata, you need to explicitly specify which schema contains the data you want.

11.2.3 What tables are in the database?

The simplest way to get a list of tables is with

```
table_list  <- DBI::dbListTables(con)

kable(table_list)
```

x
actor_info
customer_list
film_list
nicer_but_slower_film_list
sales_by_film_category
staff
sales_by_store
staff_list
category
film_category
country
actor
language
inventory
payment
rental
city
store
film
address
film_actor
customer

11.2.4 Digging into the `information_schema`

We usually need more detail than just a list of tables. Most SQL databases have am `information_schema` that has a standard structure to describe and control the database.

The `information_schema` is in a different schema from the default, so to connect to the `tables` table in the `information_schema` we connect to the database in a different way:

```
table_info_schema_table <- tbl(con, dbplyr::in_schema("information_schema", "tables"))
```

The `information_schema` is large and complex and contains 210 tables. So it's easy to get lost in it.

This query retrieves a list of the tables in the database that includes additional detail, not just the name of the table.

```
table_info <- table_info_schema_table %>%
  filter(table_schema == "public") %>%
  select(table_catalog, table_schema, table_name, table_type) %>%
  arrange(table_type, table_name) %>%
  collect()

kable(table_info)
```

table_catalog	table_schema	table_name	table_type
dvdrental	public	actor	BASE TABLE
dvdrental	public	address	BASE TABLE
dvdrental	public	category	BASE TABLE
dvdrental	public	city	BASE TABLE
dvdrental	public	country	BASE TABLE
dvdrental	public	customer	BASE TABLE
dvdrental	public	film	BASE TABLE
dvdrental	public	film_actor	BASE TABLE
dvdrental	public	film_category	BASE TABLE
dvdrental	public	inventory	BASE TABLE
dvdrental	public	language	BASE TABLE
dvdrental	public	payment	BASE TABLE
dvdrental	public	rental	BASE TABLE
dvdrental	public	staff	BASE TABLE
dvdrental	public	store	BASE TABLE
dvdrental	public	actor_info	VIEW
dvdrental	public	customer_list	VIEW
dvdrental	public	film_list	VIEW
dvdrental	public	nicer_but_slower_film_list	VIEW
dvdrental	public	sales_by_film_category	VIEW
dvdrental	public	sales_by_store	VIEW
dvdrental	public	staff_list	VIEW

In this context `table_catalog` is synonymous with `database`.

Notice that *VIEWS* are composites made up of one or more *BASE TABLES*.

The SQL world has its own terminology. For example `rs` is shorthand for `result set`. That's equivalent to using `df` for a `data frame`. The following SQL query returns the same information as the previous one.

```
rs <- dbGetQuery(
  con,
  "select table_catalog, table_schema, table_name, table_type
  from information_schema.tables
  where table_schema not in ('pg_catalog','information_schema')
  order by table_type, table_name
  ;"
)
kable(rs)
```

table_catalog	table_schema	table_name	table_type
dvdrental	public	actor	BASE TABLE
dvdrental	public	address	BASE TABLE
dvdrental	public	category	BASE TABLE
dvdrental	public	city	BASE TABLE
dvdrental	public	country	BASE TABLE
dvdrental	public	customer	BASE TABLE
dvdrental	public	film	BASE TABLE
dvdrental	public	film_actor	BASE TABLE
dvdrental	public	film_category	BASE TABLE
dvdrental	public	inventory	BASE TABLE
dvdrental	public	language	BASE TABLE
dvdrental	public	payment	BASE TABLE
dvdrental	public	rental	BASE TABLE
dvdrental	public	staff	BASE TABLE
dvdrental	public	store	BASE TABLE
dvdrental	public	actor_info	VIEW
dvdrental	public	customer_list	VIEW
dvdrental	public	film_list	VIEW
dvdrental	public	nicer_but_slower_film_list	VIEW
dvdrental	public	sales_by_film_category	VIEW
dvdrental	public	sales_by_store	VIEW
dvdrental	public	staff_list	VIEW

11.3 What columns do those tables contain?

Of course, the `DBI` package has a `dbListFields` function that provides the simplest way to get the minimum, a list of column names:

```
DBI::dbListFields(con, "rental")
```

```
## [1] "rental_id"    "rental_date"  "inventory_id" "customer_id"
## [5] "return_date"  "staff_id"     "last_update"
```

But the `information_schema` has a lot more useful information that we can use.

```
columns_info_schema_table <- tbl(con, dbplyr::in_schema("information_schema", "columns"))
```

Since the `information_schema` contains 1855 columns, we are narrowing our focus to just one table. This query retrieves more information about the `rental` table:

```
columns_info_schema_info <- columns_info_schema_table %>%
  filter(table_schema == "public") %>%
  select(
    table_catalog, table_schema, table_name, column_name, data_type, ordinal_position,
    character_maximum_length, column_default, numeric_precision, numeric_precision_radix
  ) %>%
  collect(n = Inf) %>%
  mutate(data_type = case_when(
           data_type == "character varying" ~ paste0(data_type, ' (', character_maximum_length, ')'),
           data_type == "real" ~ paste0(data_type, ' (', numeric_precision, ',', numeric_precision_radi
           TRUE ~ data_type)
         ) %>%
  filter(table_name == "rental") %>%
  select(-table_schema, -numeric_precision, -numeric_precision_radix)
```

```
glimpse(columns_info_schema_info)
```

```
## Observations: 7
## Variables: 7
## $ table_catalog            <chr> "dvdrental", "dvdrental", "dvdrental"...
## $ table_name               <chr> "rental", "rental", "rental", "rental...
## $ column_name              <chr> "rental_id", "rental_date", "inventor...
## $ data_type                <chr> "integer", "timestamp without time zo...
## $ ordinal_position         <int> 1, 2, 3, 4, 5, 6, 7
## $ character_maximum_length <int> NA, NA, NA, NA, NA, NA, NA
## $ column_default           <chr> "nextval('rental_rental_id_seq'::regc...
```

```
kable(columns_info_schema_info)
```

table_catalog	table_name	column_name	data_type	ordinal_position	character_maximum_
dvdrental	rental	rental_id	integer	1	
dvdrental	rental	rental_date	timestamp without time zone	2	
dvdrental	rental	inventory_id	integer	3	
dvdrental	rental	customer_id	smallint	4	
dvdrental	rental	return_date	timestamp without time zone	5	
dvdrental	rental	staff_id	smallint	6	
dvdrental	rental	last_update	timestamp without time zone	7	

11.3.1 What is the difference between a `VIEW` and a `BASE TABLE`?

The `BASE TABLE` has the underlying data in the database

```
table_info_schema_table %>%
  filter(table_schema == "public" & table_type == "BASE TABLE") %>%
  select(table_name, table_type) %>%
  left_join(columns_info_schema_table, by = c("table_name" = "table_name")) %>%
  select(
    table_type, table_name, column_name, data_type, ordinal_position,
    column_default
  ) %>%
  collect(n = Inf) %>%
  filter(str_detect(table_name, "cust")) %>%
  kable()
```

table_type	table_name	column_name	data_type	ordinal_position	column_default
BASE TABLE	customer	store_id	smallint	2	NA
BASE TABLE	customer	first_name	character varying	3	NA
BASE TABLE	customer	last_name	character varying	4	NA
BASE TABLE	customer	email	character varying	5	NA
BASE TABLE	customer	address_id	smallint	6	NA
BASE TABLE	customer	active	integer	10	NA
BASE TABLE	customer	customer_id	integer	1	nextval('customer_cu
BASE TABLE	customer	activebool	boolean	7	true
BASE TABLE	customer	create_date	date	8	('now'::text)::date
BASE TABLE	customer	last_update	timestamp without time zone	9	now()

Probably should explore how the `VIEW` is made up of data from BASE TABLEs.

```
table_info_schema_table %>%
  filter(table_schema == "public" & table_type == "VIEW") %>%
```

```
  select(table_name, table_type) %>%
  left_join(columns_info_schema_table, by = c("table_name" = "table_name")) %>%
  select(
    table_type, table_name, column_name, data_type, ordinal_position,
    column_default
  ) %>%
  collect(n = Inf) %>%
  filter(str_detect(table_name, "cust")) %>%
  kable()
```

table_type	table_name	column_name	data_type	ordinal_position	column_default
VIEW	customer_list	id	integer	1	NA
VIEW	customer_list	name	text	2	NA
VIEW	customer_list	address	character varying	3	NA
VIEW	customer_list	zip code	character varying	4	NA
VIEW	customer_list	phone	character varying	5	NA
VIEW	customer_list	city	character varying	6	NA
VIEW	customer_list	country	character varying	7	NA
VIEW	customer_list	notes	text	8	NA
VIEW	customer_list	sid	smallint	9	NA

11.3.2 What data types are found in the database?

```
columns_info_schema_info %>% count(data_type)
```

```
## # A tibble: 3 x 2
##   data_type                       n
##   <chr>                       <int>
## 1 integer                         2
## 2 smallint                        2
## 3 timestamp without time zone     3
```

11.4 Characterizing how things are named

Names are the handle for accessing the data. Tables and columns may or may not be named consistently or in a way that makes sense to you. You should look at these names *as data*.

11.4.1 Counting columns and name reuse

Pull out some rough-and-ready but useful statistics about your database. Since we are in SQL-land we talk about variables as `columns`.

```
public_tables <- columns_info_schema_table %>%
  filter(table_schema == "public") %>%
  collect()

public_tables %>% count(table_name, sort = TRUE) %>%
  kable()
```

table_name	n
film	13
staff	11
customer	10
customer_list	9
address	8
film_list	8
nicer_but_slower_film_list	8
staff_list	8
rental	7
payment	6
actor	4
actor_info	4
city	4
inventory	4
store	4
category	3
country	3
film_actor	3
film_category	3
language	3
sales_by_store	3
sales_by_film_category	2

How many *column names* are shared across tables (or duplicated)?

```
public_tables %>% count(column_name, sort = TRUE) %>% filter(n > 1)
```

```
## # A tibble: 34 x 2
##    column_name     n
##    <chr>       <int>
##  1 last_update    14
##  2 address_id      4
##  3 film_id         4
##  4 first_name      4
##  5 last_name       4
##  6 name            4
##  7 store_id        4
##  8 actor_id        3
##  9 address         3
## 10 category        3
## # ... with 24 more rows
```

How many column names are unique?

```
public_tables %>% count(column_name) %>% filter(n == 1) %>% count()
```

```
## # A tibble: 1 x 1
##      nn
##   <int>
## 1    24
```

11.5 Database keys

11.5.1 Direct SQL

How do we use this output? Could it be generated by dplyr?

```
rs <- dbGetQuery(
  con,
  "
--SELECT conrelid::regclass as table_from
select table_catalog||'.'||table_schema||'.'||table_name table_name
, conname, pg_catalog.pg_get_constraintdef(r.oid, true) as condef
FROM information_schema.columns c,pg_catalog.pg_constraint r
WHERE 1 = 1 --r.conrelid = '16485'
  AND r.contype  in ('f','p') ORDER BY 1
;"
)
glimpse(rs)
```

```
## Observations: 61,215
## Variables: 3
## $ table_name <chr> "dvdrental.information_schema.administrable_role_au...
## $ conname    <chr> "actor_pkey", "actor_pkey", "actor_pkey", "country_...
## $ condef     <chr> "PRIMARY KEY (actor_id)", "PRIMARY KEY (actor_id)",...
```

```
kable(head(rs))
```

table_name	conname	condef
dvdrental.information_schema.administrable_role_authorizations	actor_pkey	PRIMARY KEY (actor_id)
dvdrental.information_schema.administrable_role_authorizations	actor_pkey	PRIMARY KEY (actor_id)
dvdrental.information_schema.administrable_role_authorizations	actor_pkey	PRIMARY KEY (actor_id)
dvdrental.information_schema.administrable_role_authorizations	country_pkey	PRIMARY KEY (country_id)
dvdrental.information_schema.administrable_role_authorizations	country_pkey	PRIMARY KEY (country_id)
dvdrental.information_schema.administrable_role_authorizations	country_pkey	PRIMARY KEY (country_id)

The following is more compact and looks more useful. What is the difference between the two?

```
rs <- dbGetQuery(
  con,
  "select conrelid::regclass as table_from
      ,c.conname
      ,pg_get_constraintdef(c.oid)
  from pg_constraint c
  join pg_namespace n on n.oid = c.connamespace
 where c.contype in ('f','p')
   and n.nspname = 'public'
order by conrelid::regclass::text, contype DESC;
"
)
glimpse(rs)
```

```
## Observations: 33
## Variables: 3
## $ table_from           <chr> "actor", "address", "address", "category"...
## $ conname              <chr> "actor_pkey", "address_pkey", "fk_address...
## $ pg_get_constraintdef <chr> "PRIMARY KEY (actor_id)", "PRIMARY KEY (a...
```

```
kable(head(rs))
```

table_from	conname	pg_get_constraintdef
actor	actor_pkey	PRIMARY KEY (actor_id)
address	address_pkey	PRIMARY KEY (address_id)
address	fk_address_city	FOREIGN KEY (city_id) REFERENCES city(city_id)
category	category_pkey	PRIMARY KEY (category_id)
city	city_pkey	PRIMARY KEY (city_id)
city	fk_city	FOREIGN KEY (country_id) REFERENCES country(country_id)

```
dim(rs)[1]
```

```
## [1] 33
```

11.5.2 Database keys with dplyr

This query shows the primary and foreign keys in the database.

```
tables <- tbl(con, dbplyr::in_schema("information_schema", "tables"))
table_constraints <- tbl(con, dbplyr::in_schema("information_schema", "table_constraints"))
key_column_usage <- tbl(con, dbplyr::in_schema("information_schema", "key_column_usage"))
referential_constraints <- tbl(con, dbplyr::in_schema("information_schema", "referential_constraints"))
constraint_column_usage <- tbl(con, dbplyr::in_schema("information_schema", "constraint_column_usage"))

keys <- tables %>%
  left_join(table_constraints, by = c(
    "table_catalog" = "table_catalog",
    "table_schema" =  "table_schema",
    "table_name" = "table_name"
  )) %>%
  # table_constraints %>%
  filter(constraint_type %in% c("FOREIGN KEY", "PRIMARY KEY")) %>%
  left_join(key_column_usage,
            by = c(
              "table_catalog" = "table_catalog",
              "constraint_catalog" = "constraint_catalog",
              "constraint_schema" = "constraint_schema",
              "table_name" = "table_name",
              "table_schema" = "table_schema",
              "constraint_name" = "constraint_name"
              )) %>%
  # left_join(constraint_column_usage) %>% # does this table add anything useful?
  select(table_name, table_type, constraint_name, constraint_type, column_name, ordinal_position) %>%
  arrange(table_name) %>%
collect()
glimpse(keys)
```

```
## Observations: 35
## Variables: 6
## $ table_name       <chr> "actor", "address", "address", "category", "c...
## $ table_type       <chr> "BASE TABLE", "BASE TABLE", "BASE TABLE", "BA...
## $ constraint_name  <chr> "actor_pkey", "address_pkey", "fk_address_cit...
## $ constraint_type  <chr> "PRIMARY KEY", "PRIMARY KEY", "FOREIGN KEY", ...
## $ column_name      <chr> "actor_id", "address_id", "city_id", "categor...
## $ ordinal_position <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, ...
```

```r
kable(keys)
```

table_name	table_type	constraint_name	constraint_type	column_name	ordinal_pos
actor	BASE TABLE	actor_pkey	PRIMARY KEY	actor_id	
address	BASE TABLE	address_pkey	PRIMARY KEY	address_id	
address	BASE TABLE	fk_address_city	FOREIGN KEY	city_id	
category	BASE TABLE	category_pkey	PRIMARY KEY	category_id	
city	BASE TABLE	city_pkey	PRIMARY KEY	city_id	
city	BASE TABLE	fk_city	FOREIGN KEY	country_id	
country	BASE TABLE	country_pkey	PRIMARY KEY	country_id	
customer	BASE TABLE	customer_address_id_fkey	FOREIGN KEY	address_id	
customer	BASE TABLE	customer_pkey	PRIMARY KEY	customer_id	
film	BASE TABLE	film_language_id_fkey	FOREIGN KEY	language_id	
film	BASE TABLE	film_pkey	PRIMARY KEY	film_id	
film_actor	BASE TABLE	film_actor_actor_id_fkey	FOREIGN KEY	actor_id	
film_actor	BASE TABLE	film_actor_film_id_fkey	FOREIGN KEY	film_id	
film_actor	BASE TABLE	film_actor_pkey	PRIMARY KEY	actor_id	
film_actor	BASE TABLE	film_actor_pkey	PRIMARY KEY	film_id	
film_category	BASE TABLE	film_category_category_id_fkey	FOREIGN KEY	category_id	
film_category	BASE TABLE	film_category_film_id_fkey	FOREIGN KEY	film_id	
film_category	BASE TABLE	film_category_pkey	PRIMARY KEY	film_id	
film_category	BASE TABLE	film_category_pkey	PRIMARY KEY	category_id	
inventory	BASE TABLE	inventory_film_id_fkey	FOREIGN KEY	film_id	
inventory	BASE TABLE	inventory_pkey	PRIMARY KEY	inventory_id	
language	BASE TABLE	language_pkey	PRIMARY KEY	language_id	
payment	BASE TABLE	payment_customer_id_fkey	FOREIGN KEY	customer_id	
payment	BASE TABLE	payment_pkey	PRIMARY KEY	payment_id	
payment	BASE TABLE	payment_rental_id_fkey	FOREIGN KEY	rental_id	
payment	BASE TABLE	payment_staff_id_fkey	FOREIGN KEY	staff_id	
rental	BASE TABLE	rental_customer_id_fkey	FOREIGN KEY	customer_id	
rental	BASE TABLE	rental_inventory_id_fkey	FOREIGN KEY	inventory_id	
rental	BASE TABLE	rental_pkey	PRIMARY KEY	rental_id	
rental	BASE TABLE	rental_staff_id_key	FOREIGN KEY	staff_id	
staff	BASE TABLE	staff_address_id_fkey	FOREIGN KEY	address_id	
staff	BASE TABLE	staff_pkey	PRIMARY KEY	staff_id	
store	BASE TABLE	store_address_id_fkey	FOREIGN KEY	address_id	
store	BASE TABLE	store_manager_staff_id_fkey	FOREIGN KEY	manager_staff_id	
store	BASE TABLE	store_pkey	PRIMARY KEY	store_id	

What do we learn from the following query? How is it useful?

```r
rs <- dbGetQuery(
  con,
  "SELECT r.*,
  pg_catalog.pg_get_constraintdef(r.oid, true) as condef
  FROM pg_catalog.pg_constraint r
  WHERE 1=1 --r.conrelid = '16485' AND r.contype = 'f' ORDER BY 1;
  "
  )

head(rs)
```

```
##                          conname connamespace contype condeferrable
## 1 cardinal_number_domain_check        12703       c         FALSE
```

```
## 2             yes_or_no_check        12703       c         FALSE
## 3                  year_check         2200       c         FALSE
## 4                  actor_pkey         2200       p         FALSE
## 5                address_pkey         2200       p         FALSE
## 6               category_pkey         2200       p         FALSE
##   condeferred convalidated conrelid contypid conindid confrelid
## 1       FALSE         TRUE        0    12716        0         0
## 2       FALSE         TRUE        0    12724        0         0
## 3       FALSE         TRUE        0    16397        0         0
## 4       FALSE         TRUE    16420        0    16555         0
## 5       FALSE         TRUE    16461        0    16557         0
## 6       FALSE         TRUE    16427        0    16559         0
##   confupdtype confdeltype confmatchtype conislocal coninhcount
## 1                                            TRUE           0
## 2                                            TRUE           0
## 3                                            TRUE           0
## 4                                            TRUE           0
## 5                                            TRUE           0
## 6                                            TRUE           0
##   connoinherit conkey confkey conpfeqop conppeqop conffeqop conexclop
## 1        FALSE   <NA>    <NA>      <NA>      <NA>      <NA>      <NA>
## 2        FALSE   <NA>    <NA>      <NA>      <NA>      <NA>      <NA>
## 3        FALSE   <NA>    <NA>      <NA>      <NA>      <NA>      <NA>
## 4         TRUE    {1}    <NA>      <NA>      <NA>      <NA>      <NA>
## 5         TRUE    {1}    <NA>      <NA>      <NA>      <NA>      <NA>
## 6         TRUE    {1}    <NA>      <NA>      <NA>      <NA>      <NA>
##
## 1
## 2 {SCALARARRAYOPEXPR :opno 98 :opfuncid 67 :useOr true :inputcollid 100 :args ({RELABELTYPE :arg {COERCET
## 3                                                                                      {BOOLEXPR :boolop and :args
## 4
## 5
## 6
##                                                                                                       consrc
## 1                                                                                               (VALUE >= 0)
## 2 ((VALUE)::text = ANY ((ARRAY['YES'::character varying, 'NO'::character varying])::text[]))
## 3                                                                   ((VALUE >= 1901) AND (VALUE <= 2155))
## 4                                                                                                       <NA>
## 5                                                                                                       <NA>
## 6                                                                                                       <NA>
##                                                                                                       condef
## 1                                                                                         CHECK (VALUE >= 0)
## 2 CHECK (VALUE::text = ANY (ARRAY['YES'::character varying, 'NO'::character varying]::text[]))
## 3                                                                 CHECK (VALUE >= 1901 AND VALUE <= 2155)
## 4                                                                                 PRIMARY KEY (actor_id)
## 5                                                                               PRIMARY KEY (address_id)
## 6                                                                              PRIMARY KEY (category_id)
```

11.6 Creating your own data dictionary

If you are going to work with a database for an extended period it can be useful to create your own data dictionary. Here is an illustration of the idea

```r
some_tables <- c("rental", "city", "store")

all_meta <- map_df(some_tables, sp_get_dbms_data_dictionary, con = con)

all_meta
```

```
## # A tibble: 15 x 11
##    table_name var_name var_type num_rows num_blank num_unique min   q_25
##    <chr>      <chr>    <chr>       <int>     <int>      <int> <chr> <chr>
##  1 rental     rental_~ integer     16044         0      16044 1     4013
##  2 rental     rental_~ double      16044         0      15815 2005~ 2005~
##  3 rental     invento~ integer     16044         0       4580 1     1154
##  4 rental     custome~ integer     16044         0        599 1     148
##  5 rental     return_~ double      16044       183      15836 2005~ 2005~
##  6 rental     staff_id integer     16044         0          2 1     1
##  7 rental     last_up~ double      16044         0          3 2006~ 2006~
##  8 city       city_id  integer       600         0        600 1     150
##  9 city       city     charact~      600         0        599 A Co~ Dzer~
## 10 city       country~ integer       600         0        109 1     28
## 11 city       last_up~ double        600         0          1 2006~ 2006~
## 12 store      store_id integer         2         0          2 1     1
## 13 store      manager~ integer         2         0          2 1     1
## 14 store      address~ integer         2         0          2 1     1
## 15 store      last_up~ double          2         0          1 2006~ 2006~
## # ... with 3 more variables: q_50 <chr>, q_75 <chr>, max <chr>
```

```r
glimpse(all_meta)
```

```
## Observations: 15
## Variables: 11
## $ table_name <chr> "rental", "rental", "rental", "rental", "rental", "...
## $ var_name   <chr> "rental_id", "rental_date", "inventory_id", "custom...
## $ var_type   <chr> "integer", "double", "integer", "integer", "double"...
## $ num_rows   <int> 16044, 16044, 16044, 16044, 16044, 16044, 16044, 60...
## $ num_blank  <int> 0, 0, 0, 0, 183, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
## $ num_unique <int> 16044, 15815, 4580, 599, 15836, 2, 3, 600, 599, 109...
## $ min        <chr> "1", "2005-05-24 22:53:30", "1", "1", "2005-05-25 2...
## $ q_25       <chr> "4013", "2005-07-07 00:58:00", "1154", "148", "2005...
## $ q_50       <chr> "8025", "2005-07-28 16:03:27", "2291", "296", "2005...
## $ q_75       <chr> "12037", "2005-08-17 21:13:35", "3433", "446", "200...
## $ max        <chr> "16049", "2006-02-14 15:16:03", "4581", "599", "200...
```

```r
kable(head(all_meta))
```

table_name	var_name	var_type	num_rows	num_blank	num_unique	min	q_25
rental	rental_id	integer	16044	0	16044	1	4013
rental	rental_date	double	16044	0	15815	2005-05-24 22:53:30	2005-07-07 00:
rental	inventory_id	integer	16044	0	4580	1	1154
rental	customer_id	integer	16044	0	599	1	148
rental	return_date	double	16044	183	15836	2005-05-25 23:55:21	2005-07-10 15:
rental	staff_id	integer	16044	0	2	1	1

11.7 Save your work!

The work you do to understand the structure and contents of a database can be useful for others (including future-you). So at the end of a session, you might look at all the data frames you want to save. Consider saving them in a form where you can add notes at the appropriate level (as in a Google Doc representing table or columns that you annotate over time).

```
ls()
```

```
##  [1] "all_meta"                    "columns_info_schema_info"
##  [3] "columns_info_schema_table" "con"
##  [5] "constraint_column_usage"   "cranex"
##  [7] "key_column_usage"          "keys"
##  [9] "public_tables"             "referential_constraints"
## [11] "rental"                    "rs"
## [13] "some_tables"               "table_constraints"
## [15] "table_info"                "table_info_schema_table"
## [17] "table_list"                "tables"
```

Chapter 12

Explain queries (71)

- examining `dplyr` queries (`dplyr::show_query` on the R side v EXPLAIN on the PostgreSQL side)

Start up the `docker-pet` container

```
sp_docker_start("sql-pet")
```

now connect to the database with R

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)
```

12.1 Performance considerations

```
## Explain a `dplyr::join`

## Explain the quivalent SQL join
rs1 <- DBI::dbGetQuery(con
                 ,"SELECT c.*
                     FROM pg_catalog.pg_class c
                     JOIN pg_catalog.pg_namespace n ON n.oid = c.relnamespace
                    WHERE  n.nspname = 'public'
                      AND  c.relname = 'cust_movies'
                      AND  c.relkind = 'r'
                   ;
                 "
                 )
head(rs1)
```

```
##  [1] relname             relnamespace        reltype
##  [4] reloftype           relowner            relam
##  [7] relfilenode         reltablespace       relpages
## [10] reltuples           relallvisible       reltoastrelid
## [13] relhasindex         relisshared         relpersistence
## [16] relkind             relnatts            relchecks
## [19] relhasoids          relhaspkey          relhasrules
## [22] relhastriggers      relhassubclass      relrowsecurity
```

```
## [25] relforcerowsecurity relispopulated      relreplident
## [28] relispartition      relfrozenxid        relminmxid
## [31] relacl              reloptions          relpartbound
## <0 rows> (or 0-length row.names)
```

This came from 14-sql_pet-examples-part-b.Rmd

```
rs1 <- DBI::dbGetQuery(con,
                "explain select r.*
                   from rental r
                 ;"
                )
head(rs1)
```

```
##                                                         QUERY PLAN
## 1 Seq Scan on rental r  (cost=0.00..310.44 rows=16044 width=36)
```

```
rs2 <- DBI::dbGetQuery(con,
                "explain select count(*) count
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                    where p.rental_id is null
                 ;")
head(rs2)
```

```
##                                                                                  QUERY PLAN
## 1                                     Aggregate  (cost=2086.78..2086.80 rows=1 width=8)
## 2                              ->  Merge Anti Join  (cost=0.57..2066.73 rows=8022 width=0)
## 3                                            Merge Cond: (r.rental_id = p.rental_id)
## 4          ->  Index Only Scan using rental_pkey on rental r  (cost=0.29..1024.95 rows=16044 width=4)
## 5      ->  Index Only Scan using idx_fk_rental_id on payment p  (cost=0.29..819.23 rows=14596 width=4)
```

```
rs3 <- DBI::dbGetQuery(con,
                "explain select sum(f.rental_rate) open_amt,count(*) count
                   from rental r
                        left outer join payment p
                          on r.rental_id = p.rental_id
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                    where p.rental_id is null
                 ;")
head(rs3)
```

```
##                                                                       QUERY PLAN
## 1                         Aggregate  (cost=2353.64..2353.65 rows=1 width=40)
## 2                    ->  Hash Join  (cost=205.14..2313.53 rows=8022 width=12)
## 3                                          Hash Cond: (i.film_id = f.film_id)
## 4                     ->  Hash Join  (cost=128.64..2215.88 rows=8022 width=2)
## 5                                Hash Cond: (r.inventory_id = i.inventory_id)
## 6                 ->  Merge Anti Join  (cost=0.57..2066.73 rows=8022 width=4)
```

```
rs4 <- DBI::dbGetQuery(con,
                "explain select c.customer_id,c.first_name,c.last_name,sum(f.rental_rate) open_amt,coun
                   from rental r
                        left outer join payment p
```

```
                          on r.rental_id = p.rental_id
                        join inventory i
                          on r.inventory_id = i.inventory_id
                        join film f
                          on i.film_id = f.film_id
                        join customer c
                          on r.customer_id = c.customer_id
                  where p.rental_id is null
                  group by c.customer_id,c.first_name,c.last_name
                  order by open_amt desc
                 ;"
                )
head(rs4)
```

```
##                                                          QUERY PLAN
## 1                  Sort  (cost=2452.49..2453.99 rows=599 width=260)
## 2                               Sort Key: (sum(f.rental_rate)) DESC
## 3     ->  HashAggregate  (cost=2417.37..2424.86 rows=599 width=260)
## 4                                          Group Key: c.customer_id
## 5         ->  Hash Join  (cost=227.62..2357.21 rows=8022 width=232)
## 6                         Hash Cond: (r.customer_id = c.customer_id)
```

12.2 Clean up

```
# dbRemoveTable(con, "cars")
# dbRemoveTable(con, "mtcars")
# dbRemoveTable(con, "cust_movies")

# diconnect from the db
dbDisconnect(con)

sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Chapter 13

SQL queries behind the scenes (72)

Start up the `docker-pet` container

```
sp_docker_start("sql-pet")
```

now connect to the database with R

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)
```

13.1 SQL Execution Steps

- Parse the incoming SQL query
- Compile the SQL query
- Plan/optimize the data acquisition path
- Execute the optimized query / acquire and return data

```
dbWriteTable(con, "mtcars", mtcars, overwrite = TRUE)
rs <- dbSendQuery(con, "SELECT * FROM mtcars WHERE cyl = 4")
dbFetch(rs)
```

```
##     mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1  22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## 2  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## 3  22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## 4  32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## 5  30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## 6  33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## 7  21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
## 8  27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## 9  26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## 10 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## 11 21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

```
dbClearResult(rs)
```

13.2 Passing values to SQL statements

```
#Pass one set of values with the param argument:
rs <- dbSendQuery(con,"SELECT * FROM mtcars WHERE cyl = 4")
dbFetch(rs)
```

```
##     mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1  22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## 2  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## 3  22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## 4  32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## 5  30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## 6  33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## 7  21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
## 8  27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## 9  26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## 10 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## 11 21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

```
dbClearResult(rs)
```

13.3 Pass multiple sets of values with dbBind():

```
rs <- dbSendQuery(con, "SELECT * FROM mtcars WHERE cyl = $1")
dbBind(rs, list(6L)) # cyl = 6
dbFetch(rs)
```

```
##    mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1 21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## 2 21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## 3 21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## 4 18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
## 5 19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
## 6 17.8   6 167.6 123 3.92 3.440 18.90  1  0    4    4
## 7 19.7   6 145.0 175 3.62 2.770 15.50  0  1    5    6
```

```
dbBind(rs, list(8L)) # cyl = 8
dbFetch(rs)
```

```
##     mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1  18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## 2  14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
## 3  16.4   8 275.8 180 3.07 4.070 17.40  0  0    3    3
## 4  17.3   8 275.8 180 3.07 3.730 17.60  0  0    3    3
## 5  15.2   8 275.8 180 3.07 3.780 18.00  0  0    3    3
## 6  10.4   8 472.0 205 2.93 5.250 17.98  0  0    3    4
## 7  10.4   8 460.0 215 3.00 5.424 17.82  0  0    3    4
## 8  14.7   8 440.0 230 3.23 5.345 17.42  0  0    3    4
## 9  15.5   8 318.0 150 2.76 3.520 16.87  0  0    3    2
## 10 15.2   8 304.0 150 3.15 3.435 17.30  0  0    3    2
## 11 13.3   8 350.0 245 3.73 3.840 15.41  0  0    3    4
## 12 19.2   8 400.0 175 3.08 3.845 17.05  0  0    3    2
## 13 15.8   8 351.0 264 4.22 3.170 14.50  0  1    5    4
## 14 15.0   8 301.0 335 3.54 3.570 14.60  0  1    5    8
```

```
dbClearResult(rs)
```

13.4 Clean up

```
# dbRemoveTable(con, "cars")
dbRemoveTable(con, "mtcars")
# dbRemoveTable(con, "cust_movies")

# diconnect from the db
dbDisconnect(con)

sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Chapter 14

Writing to the DBMS (73)

Start up the `docker-pet` container

```
sp_docker_start("sql-pet")
```

now connect to the database with R

```
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                                  password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                                  dbname = "dvdrental",
                                  seconds_to_test = 10)
```

14.1 create a new table

This is an example from the DBI help file

```
dbWriteTable(con, "cars", head(cars, 3)) # "cars" is a built-in dataset, not to be confused with mtcars
dbReadTable(con, "cars")   # there are 3 rows
```

```
##   speed dist
## 1     4    2
## 2     4   10
## 3     7    4
```

14.2 Modify an existing table

```
dbExecute(
  con,
  "INSERT INTO cars (speed, dist) VALUES (1, 1), (2, 2), (3, 3)"
)
```

```
## [1] 3
```

```
dbReadTable(con, "cars")   # there are now 6 rows
```

```
##   speed dist
## 1     4    2
## 2     4   10
## 3     7    4
```

```
## 4     1    1
## 5     2    2
## 6     3    3
```

```
# Pass values using the param argument:
dbExecute(
  con,
  "INSERT INTO cars (speed, dist) VALUES ($1, $2)",
  param = list(4:7, 5:8)
)
```

```
## [1] 4
```

```
dbReadTable(con, "cars")   # there are now 10 rows
```

```
##    speed dist
## 1      4    2
## 2      4   10
## 3      7    4
## 4      1    1
## 5      2    2
## 6      3    3
## 7      4    5
## 8      5    6
## 9      6    7
## 10     7    8
```

14.3 Clean up

```
dbRemoveTable(con, "cars")

# diconnect from the db
dbDisconnect(con)

sp_docker_stop("sql-pet")
```

```
## [1] "sql-pet"
```

Chapter 15

Other resources

15.1 Editing this book

- Here are instructions for editing this tutorial

15.2 Docker alternatives

- Choosing between Docker and Vagrant

15.3 Docker and R

- Noam Ross' talk on Docker for the UseR and his Slides give a lot of context and tips.
- Good Docker tutorials
  - An introductory Docker tutorial
  - A Docker curriculum
- Scott Came's materials about Docker and R on his website and at the 2018 UseR Conference focus on **R inside Docker**.
- It's worth studying the ROpensci Docker tutorial

15.4 Documentation for Docker and Postgres

- The Postgres image documentation
- Dockerize PostgreSQL
- Postgres & Docker documentation
- Usage examples of Postgres with Docker

15.5 More Resources

- David Severski describes some key elements of connecting to databases with R for MacOS users
- This tutorial picks up ideas and tips from Ed Borasky's Data Science pet containers, which creates a framework based on that Hack Oregon example and explains why this repo is named pet-sql.

Chapter 16

Mapping your local environment (92)

16.1 Environment Tools Used in this Chapter

Note that `tidyverse`, `DBI`, `RPostgres`, `glue`, and `knitr` are loaded. Also, we've sourced the `[db-login-batch-code.R]('r-database-docker/book-src/db-login-batch-code.R')` file which is used to log in to PostgreSQL.

library(rstudioapi)

The following code block defines Tool and versions for the graph that follows. The information order corresponds to the order shown in the graph.

```
library(DiagrammeR)

## OS information
os_lbl <- .Platform$OS.type
os_ver <- 0
if (os_lbl == 'windows') {
  os_ver <- system2('cmd',stdout = TRUE) %>%
    grep(x = .,pattern = 'Microsoft Windows \\[',value = TRUE) %>%
    gsub(x = .,pattern = "^Microsoft.+Version |\\]", replace = '')
}

if (os_lbl == 'unix' || os_lbl == 'Linux' || os_lbl == 'Mac') {
  os_ver <- system2('uname', '-r', stdout = TRUE)
}

## Command line interface into Docker Apps
## CLI/system2
cli <- array(dim = 3)
cli[1] <- "docker [OPTIONS] COMMAND ARGUMENTS\n\nsystem2(docker,[OPTIONS,]\n, COMMAND,ARGUMENTS)"
cli[2] <- 'docker exec -it sql-pet bash\n\nsystem2(docker,exec -it sql-pet bash)'
cli[3] <- 'docker exec -ti sql-pet psql -a \n-p 5432 -d dvdrental -U postgres\n\nsystem2(docker,exec -ti

# R Information
r_lbl       <- names(R.Version())[1:7]
r_ver       <- R.Version()[1:7]

# RStudio Information
rstudio_lbl <- c('RStudio version','Current program mode')
```

```
rstudio_ver <- c(as.character(rstudioapi::versionInfo()$version),rstudioapi::versionInfo()$mode)

# Docker Information
docker_lbl <- c('client version','server version')
docker_ver <- system2("docker", "version", stdout = TRUE) %>%
    grep(x = ., pattern = 'Version',value = TRUE) %>%
    gsub(x = ., pattern = ' +Version: +', replacement = '')

# Linux Information
linux_lbl <- 'Linux Version'
linux_ver <- system2('docker', 'exec -i sql-pet /bin/uname -r', stdout = TRUE)

# Postgres Information
con <- sp_get_postgres_connection(user = Sys.getenv("DEFAULT_POSTGRES_USER_NAME"),
                         password = Sys.getenv("DEFAULT_POSTGRES_PASSWORD"),
                         dbname = "dvdrental",
                         seconds_to_test = 10)

postgres_ver <- dbGetQuery(con,"select version()") %>%
  gsub(x = ., pattern = '\\(.*$', replacement = '')
```

The following code block uses the data generated from the previous code block as input to the subgraphs, the ones outlined in red. The application nodes are the parents of the subgraphs and are not outlined in red. The `Environment` application node represents the machine you are running the tutorial on and hosts the sub-applications.

Note that the '@@' variables are populated at the end of the `Environment` definition following the `## @@1 - @@5` source data comment.

```
grViz("
digraph Envgraph {

  # graph, node, and edge definitions
  graph [compound = true, nodesep = .5, ranksep = .25,
         color = red]

  node [fontname = Helvetica, fontcolor = darkslategray,
        shape = rectangle, fixedsize = true, width = 1,
        color = darkslategray]

  edge [color = grey, arrowhead = none, arrowtail = none]

  # subgraph for Environment information
  subgraph cluster1 {
    node [fixedsize = true, width = 3]
    '@@1-1'
  }

  # subgraph for R information
  subgraph cluster2 {
    node [fixedsize = true, width = 3]
    '@@2-1' -> '@@2-2' -> '@@2-3' -> '@@2-4'
    '@@2-4' -> '@@2-5' -> '@@2-6' -> '@@2-7'
  }
```

```
  # subgraph for RStudio information
  subgraph cluster3 {
    node [fixedsize = true, width = 3]
    '@@3-1' -> '@@3-2'
  }

  # subgraph for Docker information
  subgraph cluster4 {
    node [fixedsize = true, width = 3]
    '@@4-1' -> '@@4-2'
  }

  # subgraph for Docker-Linux information
  subgraph cluster5 {
    node [fixedsize = true, width = 3]
    '@@5-1'
  }

  # subgraph for Docker-Postgres information
  subgraph cluster6 {
    node [fixedsize = true, width = 3]
    '@@6-1'
  }

  # subgraph for Docker-Postgres information
  subgraph cluster7 {
    node [fixedsize = true, height = 1.25, width = 4.0]
    '@@7-1' -> '@@7-2' -> '@@7-3'
  }

  CLI [label='CLI\nRStudio system2',height = .75,width=3.0, color = 'blue' ]
  Environment             [label = 'Linux,Mac,Windows',width = 2.5]
  Environment -> R
  Environment -> RStudio
  Environment -> Docker

  Environment -> '@@1'    [lhead = cluster1] # Environment Information
  R           -> '@@2-1'  [lhead = cluster2] # R Information
  RStudio     -> '@@3'    [lhead = cluster3] # RStudio Information
  Docker      -> '@@4'    [lhead = cluster4] # Docker Information
  Docker      -> '@@5'    [lhead = cluster5] # Docker-Linux Information
  Docker      -> '@@6'    [lhead = cluster6] # Docker-Postgres Information

  '@@1' -> CLI
  CLI         -> '@@7'    [lhead = cluster7] # CLI
  '@@7-2'     -> '@@5'
  '@@7-3'     -> '@@6'
}
[1]: paste0(os_lbl,     ':\\n', os_ver)
[2]: paste0(r_lbl,      ':\\n', r_ver)
[3]: paste0(rstudio_lbl,':\\n', rstudio_ver)
[4]: paste0(docker_lbl, ':\\n', docker_ver)
[5]: paste0(linux_lbl,  ':\\n', linux_ver)
```

```
[6]: paste0('PostgreSQL:\\n', postgres_ver)
[7]: cli
")
```

One sub-application not shown above is your local console/terminal/CLI application. In the tutorial, fully constructed docker commands are printed out and then executed. If for some reason the executed docker command fails, one can copy and paste it into your local terminal window to see additional error information. Failures seem more prevalent in the Windows environment.

16.2 Communicating with Docker Applications

In this tutorial, the two main ways to interface with the applications in the Docker container are through the CLI or the RStudio `system2` command. The blue box in the diagram above represents these two interfaces.