R, Databases and Docker

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Chapter 1

Introduction

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 emphsizes operational issues rather than analytical 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's role

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

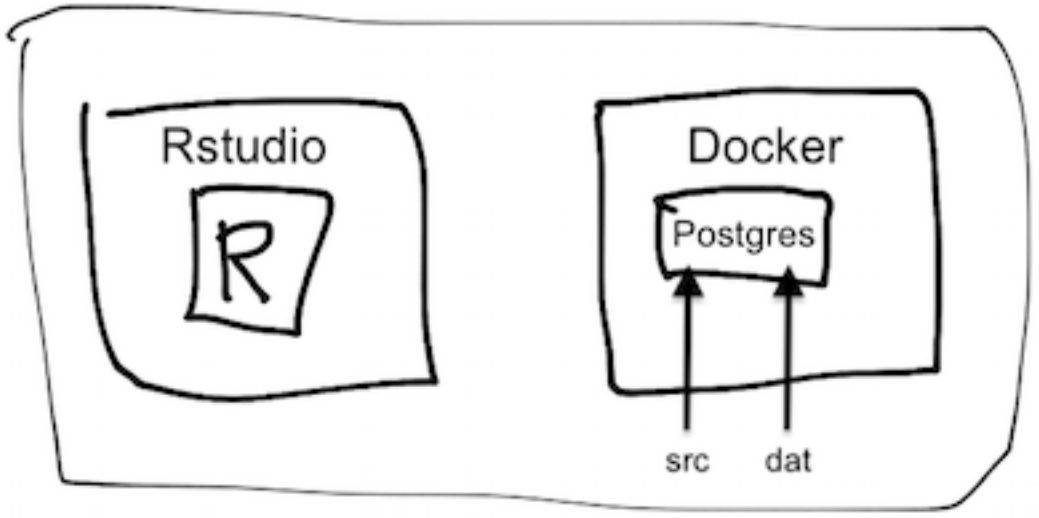
1. Make a fixed working environment for reproducible analysis
2. Access a service outside of R **(e.g., Postgres)**
3. Create an R based service (e.g., with `plumber`)
4. Send our compute jobs to the cloud with minimal reconfiguration or revision

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 PostgresSQL 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?

- M. Edward (Ed) Borasky - @znmeb
- John David Smith - @smithjd
- Scott Came - @scottcame
- Ian Franz - @ianfrantz
- Sophie Yang - @SophieMYang
- Jim Tyhurst - @jimtyhurst
- Paul Refalo - @paulrefalo

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.

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 Postgress and shows how to interact with the database from R.

Chapter 2

Docker Hosting for 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!

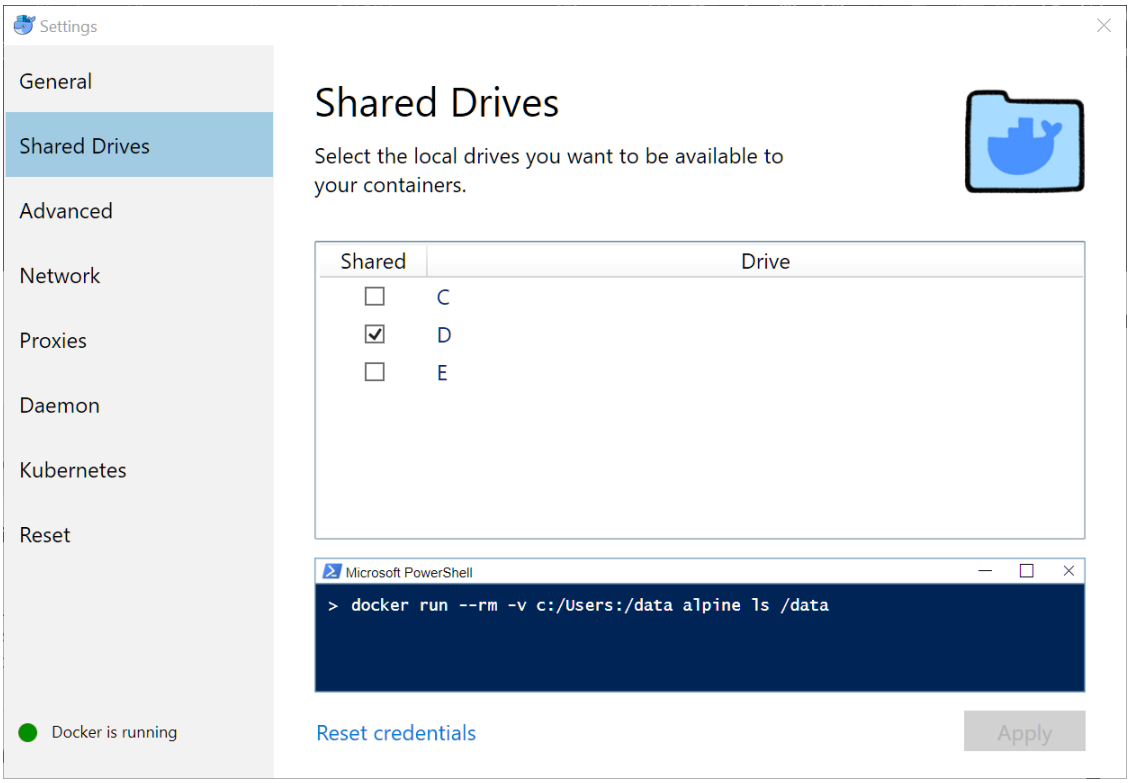
2.2.2 Windows 10 Pro

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 filesystems (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.

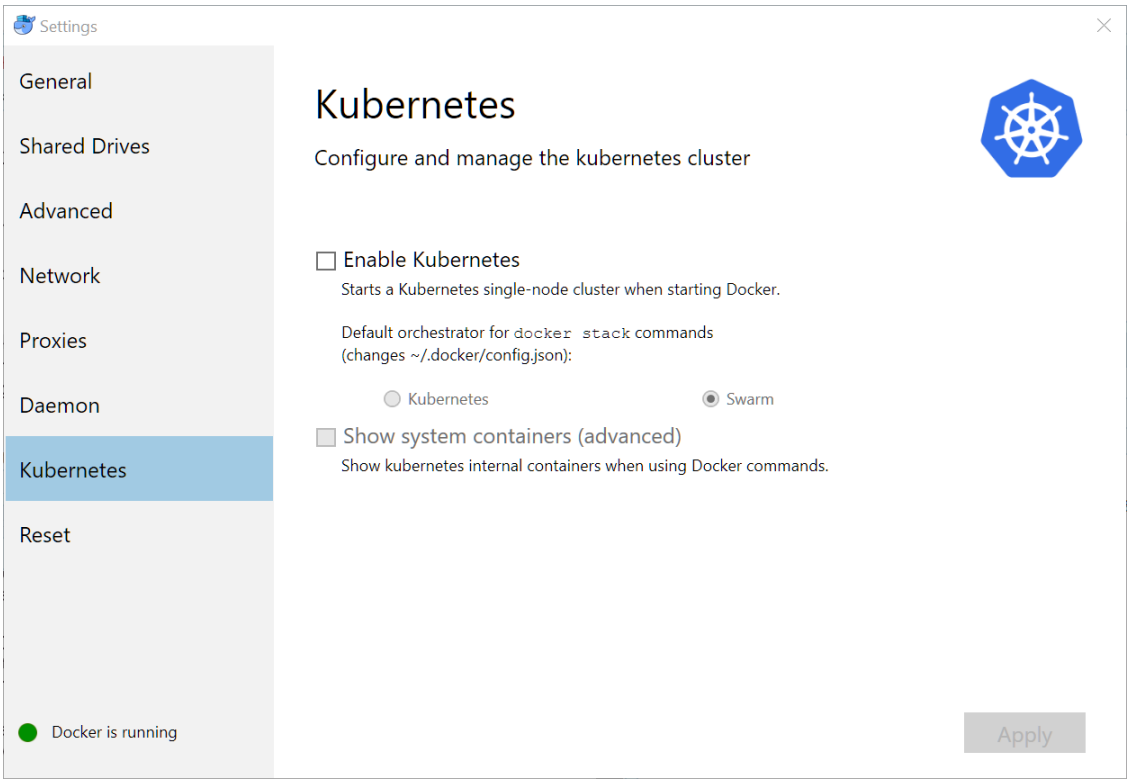


2.3.2 Kubernetes

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, it's 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

3.1 Context: Why integrate R with databases using Docker?

- 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 shuld 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 Postgres in an environment that simulates what you will find in a corporate setting.
- Understand some of the tradeoffs between queries aimed at exploration or informal investigation using dplyr and those where performance is important because of the size of the database or the frequency with which a query is run. You will be able to rewrite dplyr queries as SQL and submit them directly. You will have some understanding of techniques for assessing query structure and performance.
- Set up a Postgres database in a Docker enviornment and understand enough about Docker to swap databases, swap DBMS' (e.g., MySQL for Postgres, etc.)

3.3 Use cases

Imagine that you have one of several roles at **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.

Figure 3.1: Entity Relationship diagram for the dvdrental database

- As the Director of Analytics, you want to test as much of the production R code in my shop against a new release of the DBMS that the IT department is implementing next month.
- etc.

3.4 Environment

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

Chapter 4

Docker, Postgres, and R

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

4.1 Verify that Docker 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 comand's full output is shown in the book.

The `docker version` command returns the details about the docker daemon that is running on your computer.

```
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"
```

The convention we use in this book is to assemble a command with `paste0` so that the parts of the command can be specified separately.

```
docker_cmd <- paste0(
  "run -d --name cattle --publish 5432:5432 ",
  " postgres:10"
)
docker_cmd
```

```
## [1] "run -d --name cattle --publish 5432:5432  postgres:10"
```

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

Submit the command constructed above:

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

```
## Warning in system2("docker", docker_cmd, stdout = TRUE, stderr = TRUE):
## running command ''docker' run -d --name cattle --publish 5432:5432
## postgres:10 2>&1' had status 125
```

```
## [1] "6f517ecefe4366c73a7918c4a0e70a68f2ca4274a9052b08a54b15a9107d165a"
## [2] "docker: Error response from daemon: driver failed programming external connectivity on endpoint catt
## attr(,"status")
## [1] 125
```

Docker returns a long string of numbers. If you are running this command for the first time, Docker is downloading the Postgres image and it takes a bit of time.

The following comand shows that `postgres:10` is still running:

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

```
## [1] "CONTAINER ID      IMAGE          COMMAND                  CREATED         STATUS          PORTS
## [2] "f2e14cb8faae      postgres:10      \"docker-entrypoint.s…\"   37 seconds ago     Up 11 seconds     0
```

4.2 Connect, read and write to Postgres from R

Create a connection to Postgres after waiting 3 seconds so that Docker has time to do its thing.

```
Sys.sleep(3)

con <- DBI::dbConnect(RPostgres::Postgres(),
                      host = "localhost",
                      port = "5432",
                      user = "postgres",
                      password = "postgres")
```

Show that you can connect but that Postgres database doesn't contain any tables:

```
dbListTables(con)
```

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

Write `mtcars` to Postgres

```
dbWriteTable(con, "mtcars", mtcars)
```

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

```
dbListTables(con)
```

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

```
# 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:

```
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

4.3 Clean up

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

```
dbDisconnect(con)
system2("docker", "stop cattle", stdout = TRUE, stderr = TRUE)
```

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

```
system2("docker", "rm cattle", stdout = TRUE, stderr = TRUE)
```

```
## [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 with `start cattle`. In that case, `mtcars` would still be there and we could download it 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

5.1 Overview

You've already connected to Postgres 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 whwere 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.

Note that this approach relies on two files that have quote that's not shown here: dvdrental.Dockerfile and init-dvdrental.sh. They are discussed below.

5.2 First, 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 `pet` container if it exists (e.g., from a prior run)

```
if (system2("docker", "ps -a", stdout = TRUE) %>%
   grepl(x = ., pattern = 'pet') %>%
   any()) {
     system2("docker", "rm -f 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", "build -t postgres-dvdrental -f dvdrental.Dockerfile .", stdout = TRUE, stderr = TRUE)
```

```
##  [1] "Sending build context to Docker daemon  627.7kB\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 h
## [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 Postgres environment. There are two important parts to this that may not be obvious:

- The `source=` paramter 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 comand `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 Postgres 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 <- paste0(
```

```
  "run -d --name pet --publish 5432:5432 ",
  '--mount "type=bind,source=', wd,
  '/,target=/petdir"',
    " postgres-dvdrental"
)

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

```
## [1] "4551031ceabb0d9f1222ce6c16e05bedabbf25c7fb082f131c69bd4a12b00444"
```

5.6 Connect to Postgres with R

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

```
Sys.sleep(4)

con <- DBI::dbConnect(RPostgres::Postgres(),
                      host = "localhost",
                      port = "5432",
                      user = "postgres",
                      password = "postgres",
                      dbname = "dvdrental" ) # note that the dbname is specified

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)

Sys.sleep(2) # Can take a moment to disconnect.
```

5.7 Stop and start to demonstrate persistence

Stop the container

```
system2('docker', 'stop pet',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
Sys.sleep(3) # can take a moment for Docker to stop the container.
```

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

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
Sys.sleep(4) # need to wait for Docker & Postgres to come up before connecting.

con <- DBI::dbConnect(RPostgres::Postgres(),
                      host = "localhost",
                      port = "5432",
                      user = "postgres",
                      password = "postgres",
                      dbname = "dvdrental" ) # note that the dbname is specified

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

```
## Observations: 16,044
## 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...
```

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

```
system2('docker', 'stop pet',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
# show that the container still exists even though it's not running
psout <- system2("docker", "ps -a", stdout = TRUE)
psout[grepl(x = psout, pattern = 'pet')]
```

```
## [1] "4551031ceabb      postgres-dvdrental  \"docker-entrypoint.s…\"  26 seconds ago    Exited (137) Les
```

5.8 Cleaning up

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

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

And once stopped, the container can be removed with:

```
system2("docker",  "rm pet", stdout = TRUE, stderr = TRUE)
```

5.9 Using the 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 *pet database* with:

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

Chapter 6

A persistent database in Postgres in Docker - piecemeal

6.1 Overview

This chapter essentially repeats what was presented in the previous one, but does it in a step-by-step way that might be useful to understand how each of the steps involved in setting up a persistent Postgres database works. If you are satisfied with the method shown in that chapter, skip this one for now.

6.2 Retrieve the backup file

The first step is to get a local copy of the `dvdrental` Postgres restore file. It comes in a zip format and needs to be un-zipped. Use the `downloader` and `here` packages to keep track of things.

```
if (!require(downloader)) install.packages("downloader")
```

```
## Loading required package: downloader
```

```
if (!require(here)) install.packages("here")
```

```
## Loading required package: here
```

```
## here() starts at /Users/jds/Documents/Library/R/r-system/sql-pet/r-database-docker
```

```
library(downloader, here)

download("http://www.postgresqltutorial.com/wp-content/uploads/2017/10/dvdrental.zip", destfile = here(

unzip(here("dvdrental.zip"), exdir = here()) # creates a tar archhive named "dvdrental.tar"

file.remove(here("dvdrental.zip")) # the Zip file is no longer needed.
```

```
## [1] TRUE
```

6.3 Now, 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"
```

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

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

6.4 Build the Docker Image

Build an image that derives from postgres:10. Connect the local and Docker directories that need to be shared. Expose the standard Postgres port 5432.

```
wd <- getwd()

docker_cmd <- paste0(
  "run -d --name pet --publish 5432:5432 ",
  '--mount "type=bind,source=', wd,
  '/,target=/petdir"',
    " postgres:10"
)

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

```
## [1] "e95bedc1146ecf831d2b5d29ebec8dafe4f3542cd7c4389a19d06d3ba13f7825"
```

Peek inside the docker container and list the files in the `petdir` directory. Notice that `dvdrental.tar` is in both.

```
system2('docker', 'exec pet ls petdir | grep "dvdrental.tar" ',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "dvdrental.tar"
```

```
dir(wd, pattern = "dvdrental.tar")
```

```
## [1] "dvdrental.tar"
```

We can execute programs inside the Docker container with the `exec` command. In this case we tell Docker to execute the `psql` program inside the `pet` container and pass it some commands.

```
Sys.sleep(2)
# inside Docker, execute the postgress SQL command-line program to create the dvdrental database:
system2('docker', 'exec pet psql -U postgres -c "CREATE DATABASE dvdrental;"',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "CREATE DATABASE"
```

The `psql` program repeats back to us what it has done, e.g., to create a databse named `dvdrental`.

Next we execute a different program in the Docker container, `pg_restore`, and tell it where the restore file is located. If successful, the `pg_restore` just responds with a very laconic `character(0)`.

```
Sys.sleep(2)
# restore the database from the .tar file
system2("docker", "exec pet pg_restore -U postgres -d dvdrental petdir/dvdrental.tar", stdout = TRUE, s
```

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

```
file.remove(here("dvdrental.tar")) # the tar file is no longer needed.
```

```
## [1] TRUE
```

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

```
Sys.sleep(4)

con <- DBI::dbConnect(RPostgres::Postgres(),
                      host = "localhost",
                      port = "5432",
                      user = "postgres",
                      password = "postgres",
                      dbname = "dvdrental" ) # note that the dbname is specified

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)
```

6.5 Stop and start to demonstrate persistence

Stop the container

```
system2('docker', 'stop pet',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

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

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
Sys.sleep(1) # need to wait for Docker & Postgres to come up before connecting.

con <- DBI::dbConnect(RPostgres::Postgres(),
                      host = "localhost",
                      port = "5432",
                      user = "postgres",
                      password = "postgres",
                      dbname = "dvdrental" ) # note that the dbname is specified

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

```
## Observations: 16,044
## 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...
```

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

```
system2('docker', 'stop pet',
        stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
# show that the container still exists even though it's not running
psout <- system2("docker", "ps -a", stdout = TRUE)
psout[grepl(x = psout, pattern = 'pet')]
```

```
## [1] "e95bedc1146e      postgres:10      \"docker-entrypoint.s…\"  23 seconds ago     Exited (137) Less t
```

6.6 Cleaning up

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

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

And after disconnecting from it the container can be completely removed with:

```
system2("docker",  "rm pet -f", stdout = TRUE, stderr = TRUE)
```

6.7 Using the 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 *pet database* with:

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

Chapter 7

Introduction to interacting with Postgres from R

7.1 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.

7.2 Ask yourself about what you are 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

7.3 Get some basic information about your database

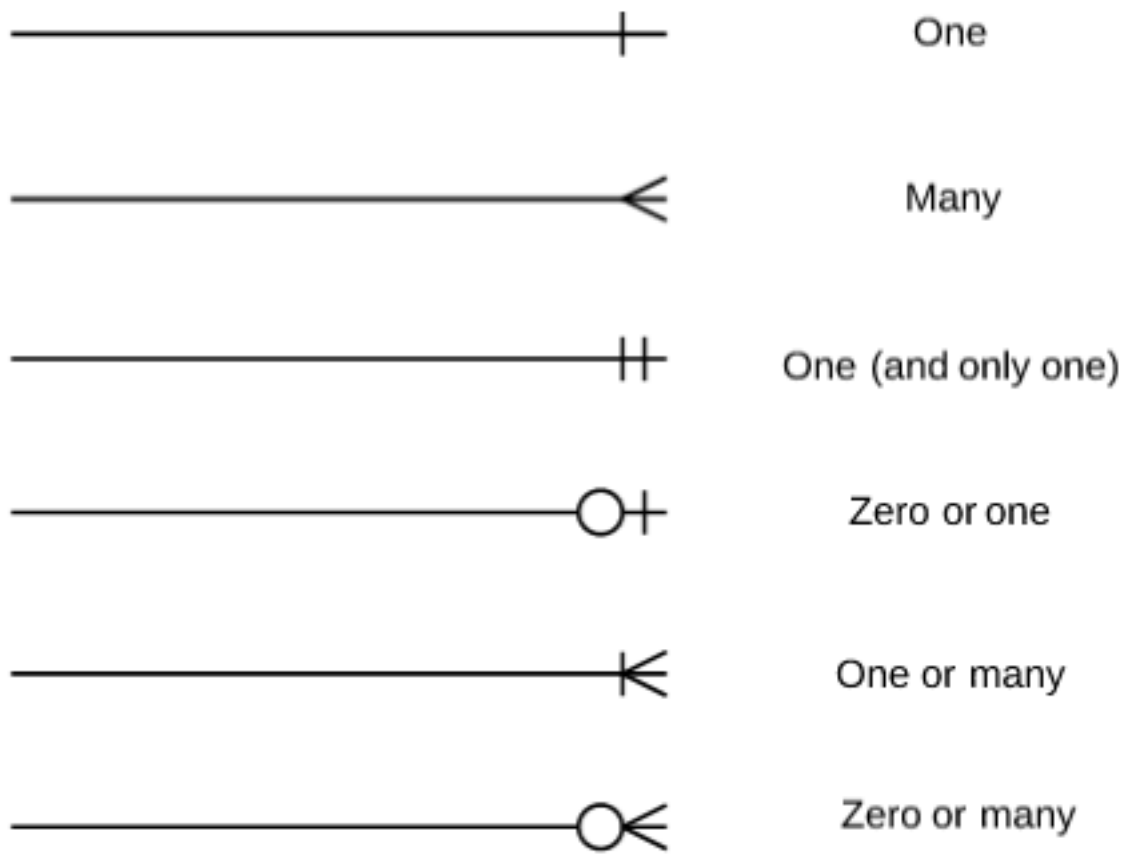
Assume that the Docker container with Postgres and the dvdrental database are ready to go.

```
system2("docker",  "start pet", stdout = TRUE, stderr = TRUE)
```

```
## [1] "pet"
```

```
Sys.sleep(2) # need to wait for Docker & Postgres to come up before connecting.
con <- DBI::dbConnect(RPostgres::Postgres(), host = "localhost",
                      port = "5432", user = "postgres",
                      password = "postgres", dbname = "dvdrental" ) # note that the dbname is specified
```

You usually need to use both the available documentation for your database and to be somewhat skeptical (e.g., empirical). It's worth learning to interpret the symbols in an Entity Relationship Diagram:



Depending on how skeptical you are about the documenttion, you might want to get an overview of a database by pulling data from the database `information_schema`. Here's a selection of useful information although you may want more (or less). There is a lot to choose from a vast list of metadata. Note that information schemas are somewhat consistent across different DBMS' that you may encounter.

have we hidden "in_schema()" as in:

```
con %>% tbl(in_schema("aux", "df"))
```

```
table_schema_query  <- paste0("SELECT ",
  "table_name, column_name, data_type, ordinal_position, column_default, character_maximum_length, is_nu
  " FROM information_schema.columns ",
  "WHERE table_schema = 'public'")

  rental_meta_data  <- dbGetQuery(con, table_schema_query)

glimpse(rental_meta_data)
```

```
## Observations: 128
## Variables: 7
## $ table_name              <chr> "actor_info", "actor_info", "actor_in...
## $ column_name             <chr> "actor_id", "first_name", "last_name"...
## $ data_type               <chr> "integer", "character varying", "char...
## $ ordinal_position        <int> 1, 2, 3, 4, 1, 2, 3, 4, 5, 6, 7, 8, 9...
## $ column_default          <chr> NA, NA, NA, NA, NA, NA, NA, NA, NA, N...
## $ character_maximum_length <int> NA, 45, 45, NA, NA, NA, 50, 10, 20, 5...
```

```
## $ is_nullable              <chr> "YES", "YES", "YES", "YES", "YES", "Y...
```

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

Start with a list of tables names and a count of the number of columns that each one contains.

```
rental_meta_data %>% count(table_name) %>% rename(number_of_columns = n) %>% as.data.frame()
```

```
##                    table_name number_of_columns
## 1                       actor                 4
## 2                  actor_info                 4
## 3                     address                 8
## 4                    category                 3
## 5                        city                 4
## 6                     country                 3
## 7                    customer                10
## 8               customer_list                 9
## 9                        film                13
## 10                 film_actor                 3
## 11              film_category                 3
## 12                  film_list                 8
## 13                  inventory                 4
## 14                   language                 3
## 15 nicer_but_slower_film_list                 8
## 16                    payment                 6
## 17                     rental                 7
## 18     sales_by_film_category                 2
## 19             sales_by_store                 3
## 20                      staff                11
## 21                 staff_list                 8
## 22                      store                 4
```

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

```
rental_meta_data %>% 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?

```
rental_meta_data %>% count(column_name) %>% filter(n > 1)
```

```
## # A tibble: 34 x 2
##    column_name     n
##    <chr>       <int>
```

```
##  1 active          2
##  2 actor_id        3
##  3 actors          2
##  4 address         3
##  5 address_id      4
##  6 category        3
##  7 category_id     2
##  8 city            3
##  9 city_id         2
## 10 country         3
## # ... with 24 more rows
```

What data types are found in the database?

```
rental_meta_data %>% count(data_type)
```

```
## # A tibble: 13 x 2
##    data_type                      n
##    <chr>                      <int>
##  1 ARRAY                          1
##  2 boolean                        2
##  3 bytea                          1
##  4 character                      1
##  5 character varying             36
##  6 date                           1
##  7 integer                       22
##  8 numeric                        7
##  9 smallint                      25
## 10 text                          11
## 11 timestamp without time zone   17
## 12 tsvector                      1
## 13 USER-DEFINED                  3
```

Chapter 8

Real work with real data

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 databse).

```
library(glue)
```

```
##
## Attaching package: 'glue'
```

```
## The following object is masked from 'package:dplyr':
##
##     collapse
```

```
library(skimr)
```

8.2 Basic investigation

- 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?

8.3 Using Dplyr

We already started, but that's OK.

8.3.1 finding out what's in the database

- DBI / RPostgres packaages

- R tools like glimpse, skimr, kable.
- examining dplyr queries (show_query on the R side v EXPLAIN on the Postges side)
- 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

8.3.2 sample query

- rental
- date subset
- left join staff
- left join customer

8.3.3 Subset: only retrieve what you need

- Columns
- Rows
  - number of row
  - specific rows
- dplyr joins in the R

8.3.4 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

8.4 What is dplyr sending to the server?

- show_query as a first draft

8.5 Writing your on SQL directly to the DBMS

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

8.6 Chosing between dplyr and native SQL

- performance considerations: first get the right data, then worory about performance
- Tradeoffs between leaving the data in Postgres 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

Chapter 9

Real work with real data

9.1 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 databse).

```
library(glue)
```

```
##
## Attaching package: 'glue'
```

```
## The following object is masked from 'package:dplyr':
##
##     collapse
```

```
library(skimr)
```

9.2 More topics

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

9.3 Standards for production jobs

- writing tests for you rqueries

Chapter 10

Other resources

10.1 Editing this book

- Here are instructions for editing this tutorial

10.2 Docker alternatives

- Chosing between Docker and Vagrant

10.3 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

10.4 Documentation Docker and Postgres

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

10.5 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.