Overview

The online directory contains software to get you started with **R**, this document and a document **R (programming language).pdf**, downloaded from Wikipedia. This document is divided into two parts: a technical part having to do with connecting to an online repository and a brief introduction to **R** and **RStudio**.

Part 1: Atlassian, Bitbucket and SourceTree

The following steps describe how to download all online files associated with the book (and **RJafroc**) onto the user's computer, where they may be modified at will without disrupting the online files, and the user always has the option to revert to the original files, by discarding all local changes. Software (**SourceTree**) will be installed that serves as an interface to **BitBucket** (an **Atlassian** website that hosts such scientific projects). **SourceTree** alerts the user to any subsequent updates to the software and/or the physical book[1].

Corrections to the book will be posted to this online repository, as well as new features to the software and improvements to algorithms. It is the author's hope that users will post questions and comments to this forum, and make suggestions for improvements. Any improvements resulting from user-input will be acknowledged.

This section is "geeky", but is necessary before one can get to the science. Persons already familiar with using online repositories like **GitHub** and **Bitbucket** probably do not need the following detailed directions. But for those who do, read on ...

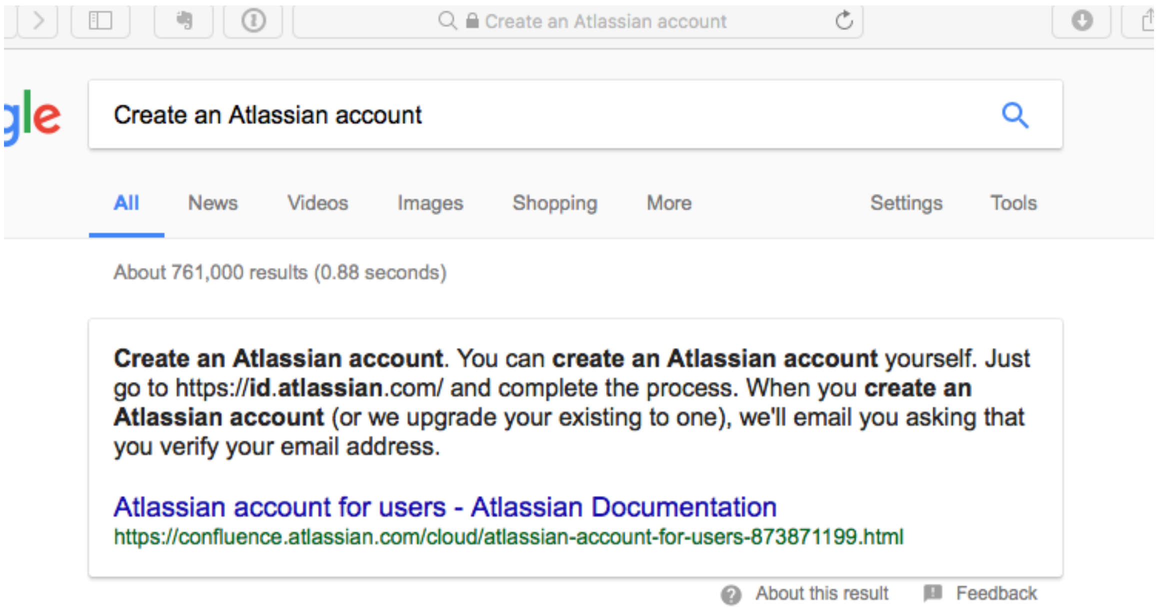
The reader should have Internet access and administrative privileges and reasonable familiarity with working with software in one's preferred computing environment. While the screen shots and directions are for a MAC, the software runs on practically any platform.

All software distributed by the author is fully open source.

Create an Atlassian/Bitbucket account

To get to the following screen, type **Create an Atlassian account** into the Google search bar and hit **Enter**, Figure 1.

[1] At the time of writing, 12/7/2017, there is a bug in **Sourcetree** that is preventing this feature; so until this is fixed, the sure way of seeing the true state of the repository is to quit **Sourcetree** and restart it. Clumsy, but it works!



Create an Atlassian account

About 761,000 results (0.88 seconds)

Create an Atlassian account. You can **create an Atlassian account** yourself. Just go to https://**id.atlassian**.com/ and complete the process. When you **create an Atlassian account** (or we upgrade your existing to one), we'll email you asking that you verify your email address.

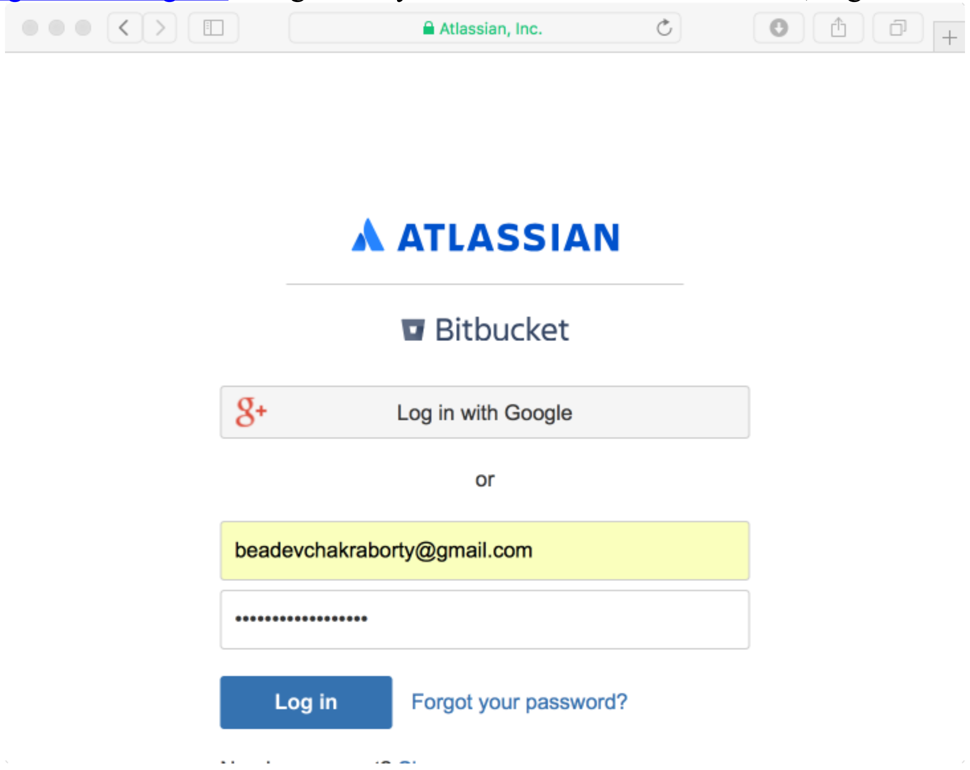
Atlassian account for users - Atlassian Documentation
https://confluence.atlassian.com/cloud/atlassian-account-for-users-873871199.html

Figure 1

Follow the directions in the above screen-shot to create an **Atlassian** account. Record your **username** and **password**. To illustrate the steps, I created a user with email beadevchakraborty@gmail.com and a password.

Generate a password to allow communication between **SourceTree** and **Bitbucket**

SourceTree is an application (**app**) that facilitates working with **Bitbucket**. Type in the following link: https://bitbucket.org/account/signin/ to sign in to your new **Bitbucket** account, Figure 2.

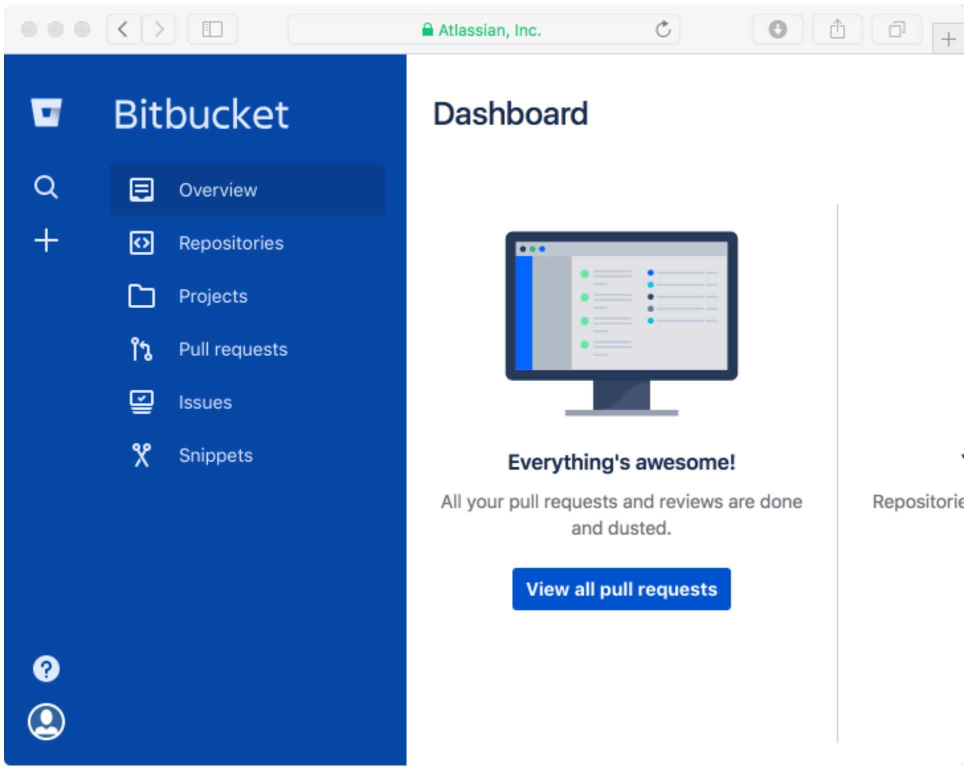


beadevchakraborty@gmail.com

••••••••••••••••••

Figure 2

After clicking on **Log in** one sees Figure 3.



Everything's awesome!

All your pull requests and reviews are done and dusted.

Figure 3

Click on the bottom-left icon (the face) and select **`Bitbucket settings`**, Figure 4.

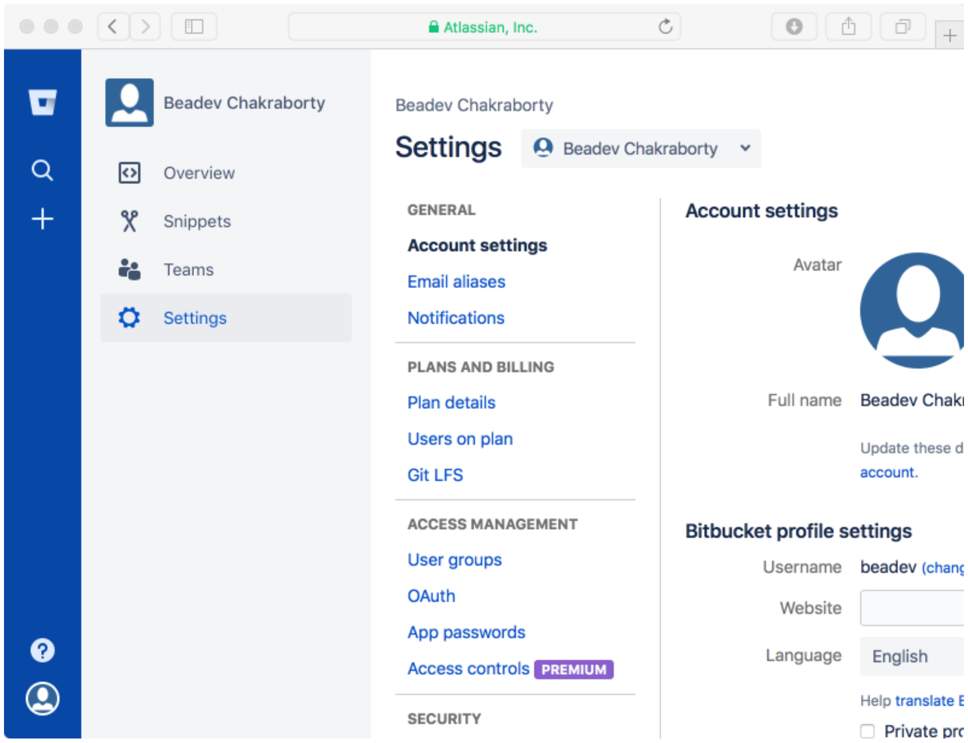
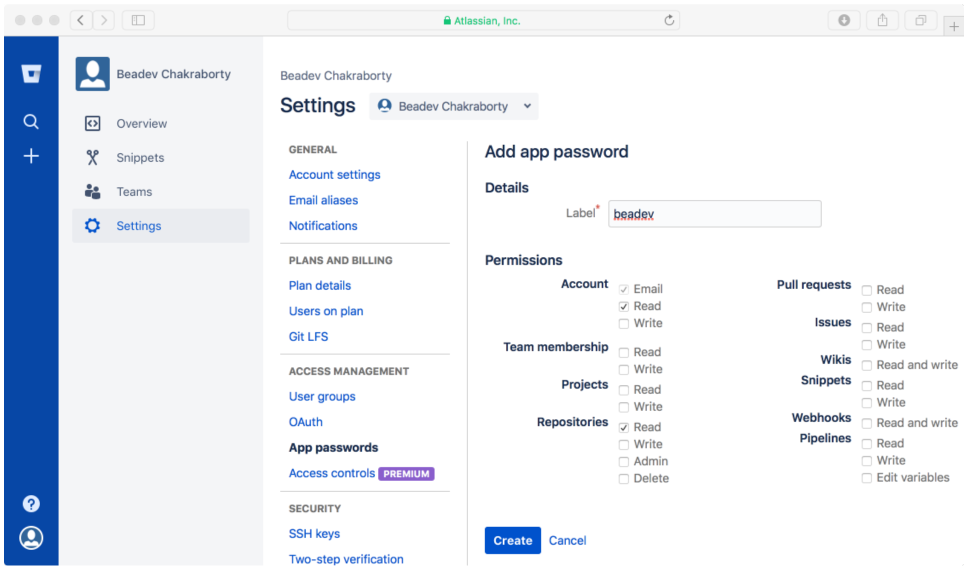


Figure 4

Click on **`App passwords`**. On the following screen click on **`Create app password`**, provide a label, which will be your username for **`SourceTree`**, and click **`Create`**, Figure 5. In the example I entered **`beadev`** as the username. This yields Figure 6, containing the automatically generated password.



Beadev Chakraborty

Settings Beadev Chakraborty

GENERAL
Account settings
Email aliases
Notifications

PLANS AND BILLING
Plan details
Users on plan
Git LFS

ACCESS MANAGEMENT
User groups
OAuth
App passwords
Access controls PREMIUM

SECURITY
SSH keys
Two-step verification

Add app password

Details

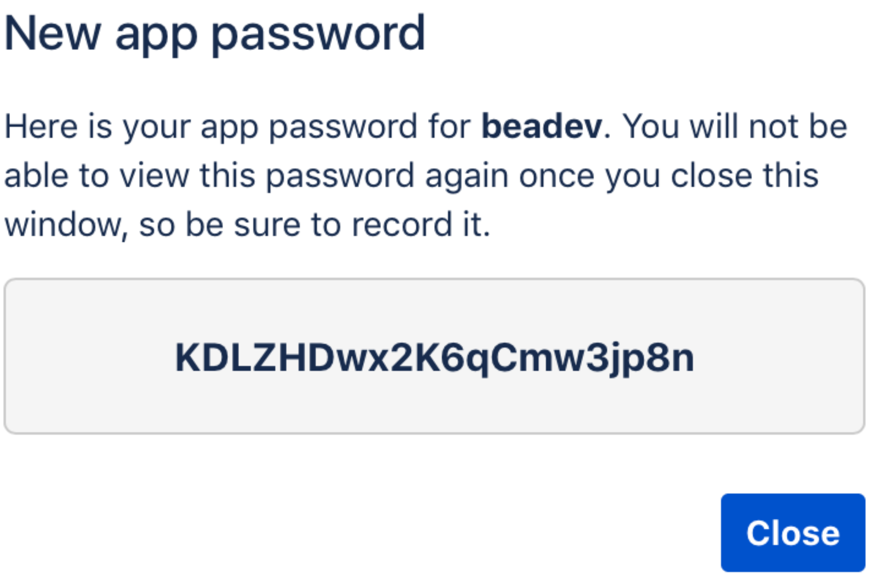
Label* beadev

Permissions

Account	✓ Email ✓ Read ☐ Write	**Pull requests**	☐ Read ☐ Write
Team membership	☐ Read ☐ Write	**Issues**	☐ Read ☐ Write
Projects	☐ Read ☐ Write	**Wikis**	☐ Read and write
Repositories	✓ Read ☐ Write ☐ Admin ☐ Delete	**Snippets**	☐ Read ☐ Write
		Webhooks	☐ Read and write
		Pipelines	☐ Read ☐ Write ☐ Edit variables

Create Cancel

Figure 5



New app password

Here is your app password for **beadev**. You will not be able to view this password again once you close this window, so be sure to record it.

KDLZHDwx2K6qCmw3jp8n

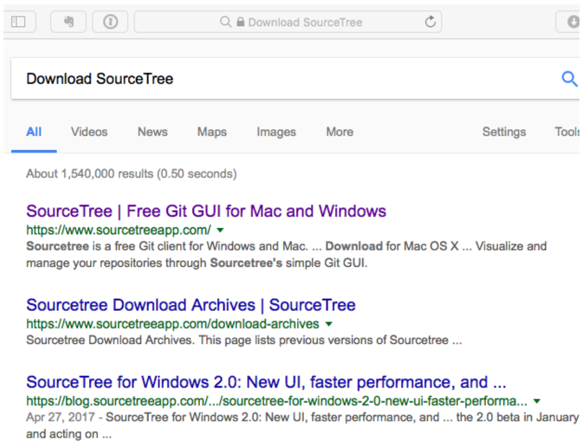
Close

Figure 6

Copy the automatically generated password and save it. You will need it to allow **SourceTree** (the app) to communicate with **Bitbucket**.

Download **SourceTree**

The next step is to download **SourceTree**, which is software that synchronizes the online book, and any subsequent changes made to it by me (Dr. Chakraborty), with the files stored on your computer.


Download SourceTree

About 1,540,000 results (0.50 seconds)

SourceTree | Free Git GUI for Mac and Windows
https://www.sourcetreeapp.com/
Sourcetree is a free Git client for Windows and Mac. ... Download for Mac OS X ... Visualize and manage your repositories through Sourcetree's simple Git GUI.

Sourcetree Download Archives | SourceTree
https://www.sourcetreeapp.com/download-archives
Sourcetree Download Archives. This page lists previous versions of Sourcetree ...

SourceTree for Windows 2.0: New UI, faster performance, and ...
https://blog.sourcetreeapp.com/.../sourcetree-for-windows-2-0-new-ui-faster-performa...
Apr 27, 2017 - SourceTree for Windows 2.0: New UI, faster performance, and ... the 2.0 beta in January and acting on ...

Figure 7

Click on the first link and install the software. Open **SourceTree**, Figure 8.

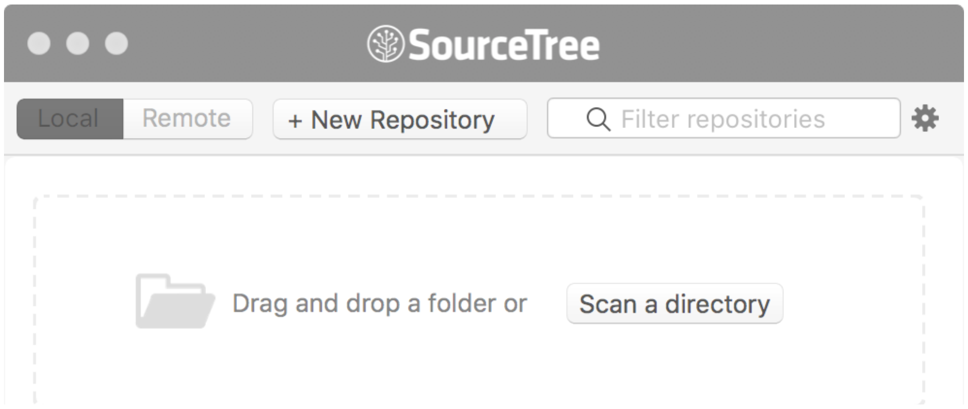


Figure 8

Click on the gear shaped icon at top-right, select **Settings**, Figure 9. [**devtemp** is coming from a new user, **devtemp**, that I created on my Mac to test the directions]

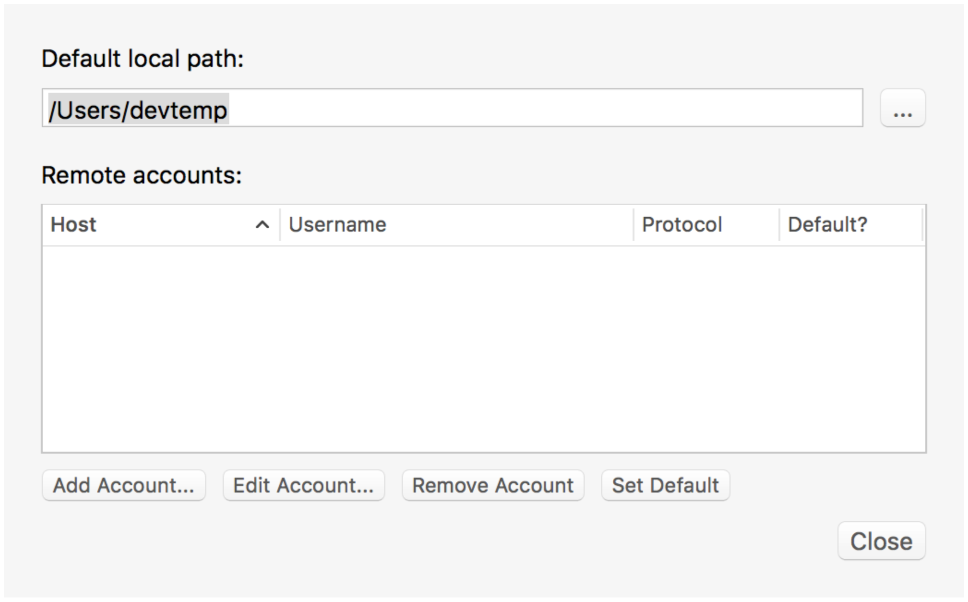
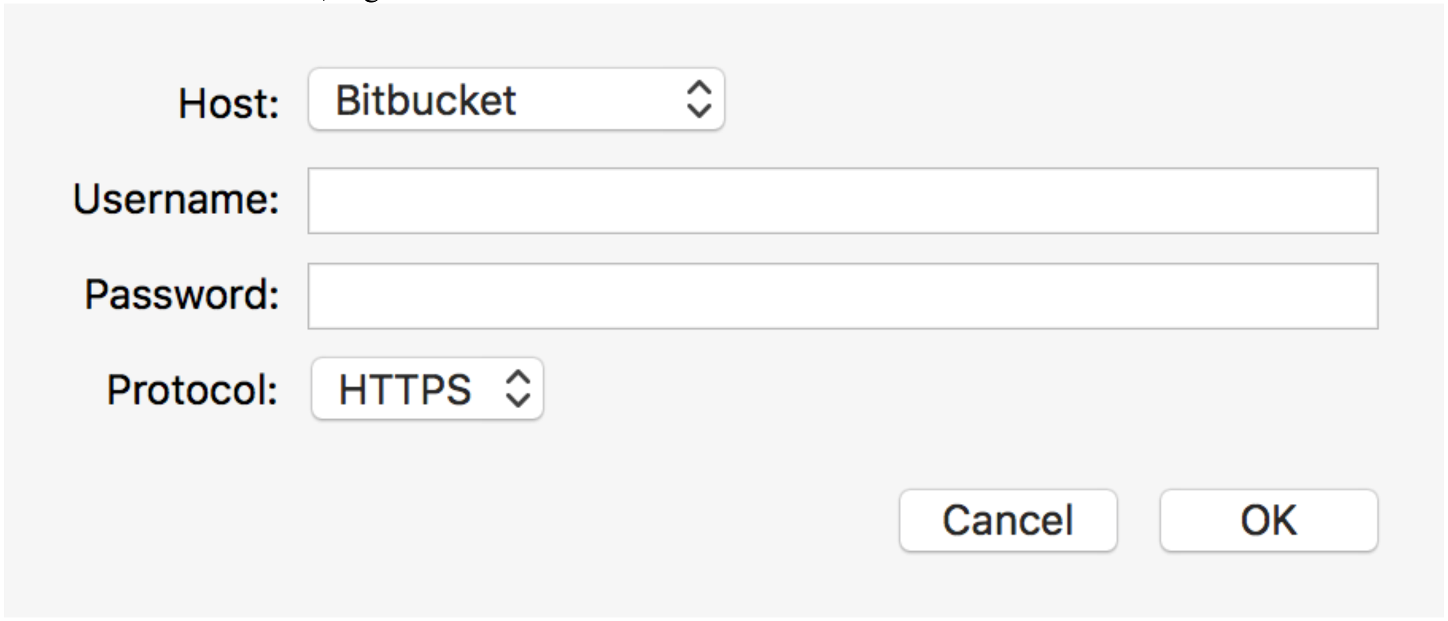

Default local path: /Users/devtemp

Figure 9

Click on **Add Account**, Figure 10.



Host: Bitbucket

Username:

Password:

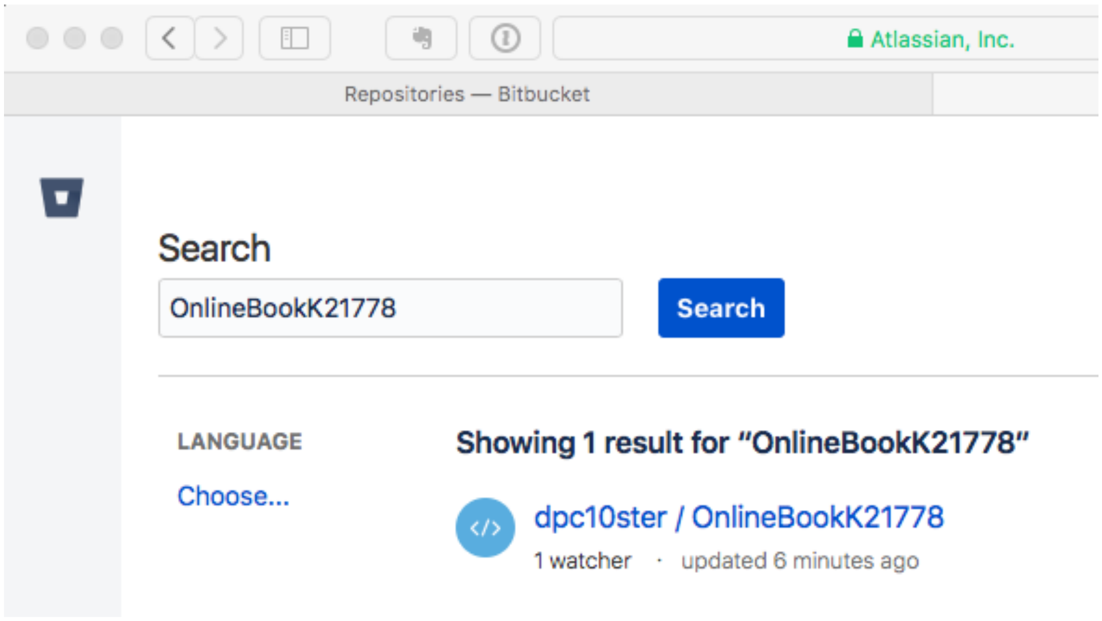
Protocol: HTTPS

Figure 10

For **Username** enter the **Atlassian/BitBucket** user name, so in the current example it would be **beadev**, and for **Password** paste the value copied from the screen in Figure 6. Click **OK** followed by **Close**.

Getting the book software

1. Type this link into your browser: https://bitbucket.org/repo/all?
2. Type **OnlineBookK21778** under **Search**
3. Click the **Search** button, Figure 11.
4. [To download **RJafroc**[2], in step 2 replace **OnlineBookK21778** with **RJafroc**.]



Search

OnlineBookK21778

Showing 1 result for "OnlineBookK21778"

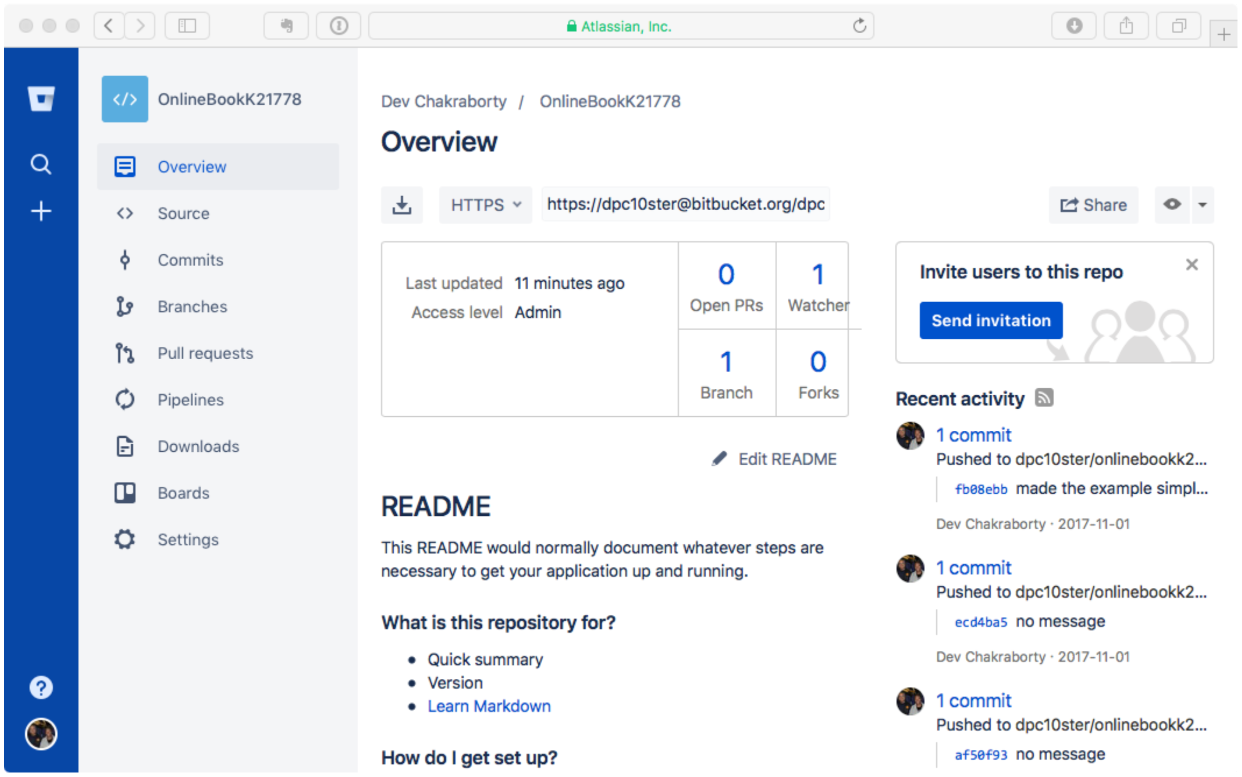
dpc10ster / OnlineBookK21778

1 watcher · updated 6 minutes ago

Figure 11

[2] This includes the entire development process of this package, i.e., intermediate versions; the final (i.e., most recent) version has not yet been uploaded to CRAN.

Click on the highlighted link: **`dpc10ster / OnlineBookK21778`**. You should see Figure 12.



Atlassian, Inc.

OnlineBookK21778

Overview
Source
Commits
Branches
Pull requests
Pipelines
Downloads
Boards
Settings

Dev Chakraborty / OnlineBookK21778

Overview

HTTPS https://dpc10ster@bitbucket.org/dpc

Share

Last updated 11 minutes ago
Access level Admin

0 Open PRs
1 Watcher
1 Branch
0 Forks

Invite users to this repo
Send invitation

Recent activity

1 commit
Pushed to dpc10ster/onlinebookk2...
fb08ebb made the example simpl...
Dev Chakraborty · 2017-11-01

1 commit
Pushed to dpc10ster/onlinebookk2...
ecd4ba5 no message
Dev Chakraborty · 2017-11-01

1 commit
Pushed to dpc10ster/onlinebookk2...
af50f93 no message

Edit README

README

This README would normally document whatever steps are necessary to get your application up and running.

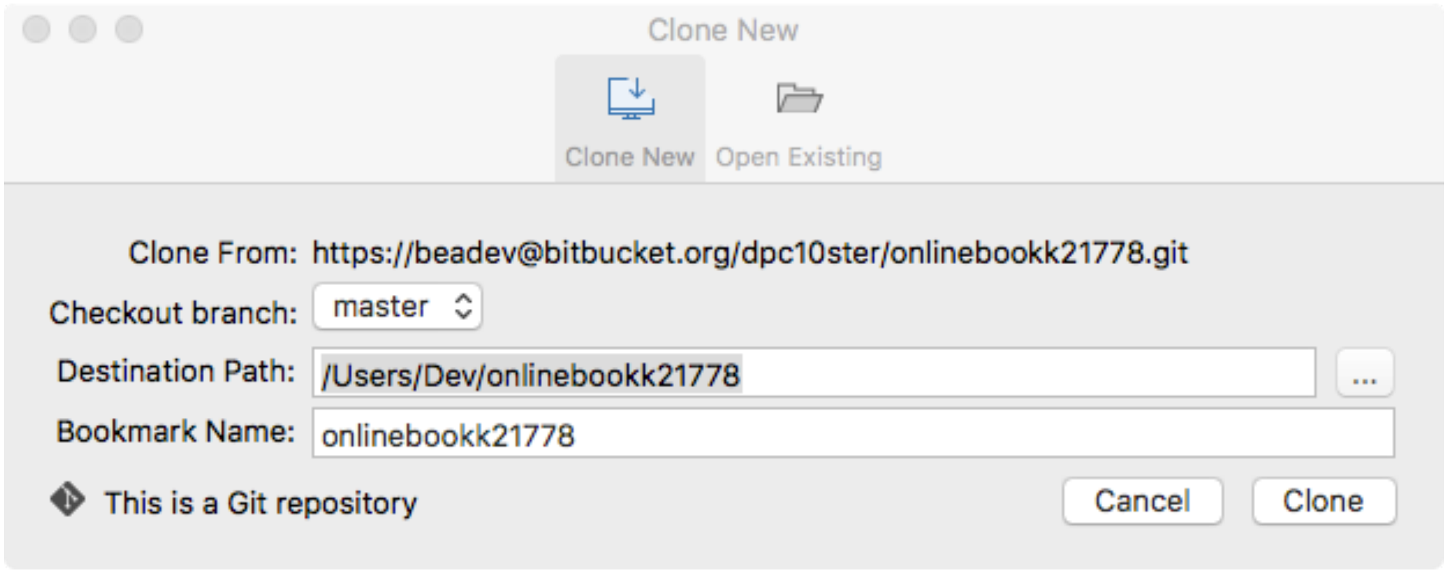
What is this repository for?

- Quick summary
- Version
- Learn Markdown

How do I get set up?

Figure 12

Under **`Overview`** there is a link perhaps described as an arrow pointed down into a shallow bucket. Hovering the cursor over it reveals the message: **`Clone in Sourcetree`**. Click on it and click **`Allow`** on the next screen, accept the default destination path and click on **`Clone`**, Figure 13.



Clone New

Clone New
Open Existing

Clone From: https://beadev@bitbucket.org/dpc10ster/onlinebookk21778.git
Checkout branch: master
Destination Path: /Users/Dev/onlinebookk21778
Bookmark Name: onlinebookk21778

This is a Git repository

Cancel
Clone

Figure 13

You should see Figure 14.

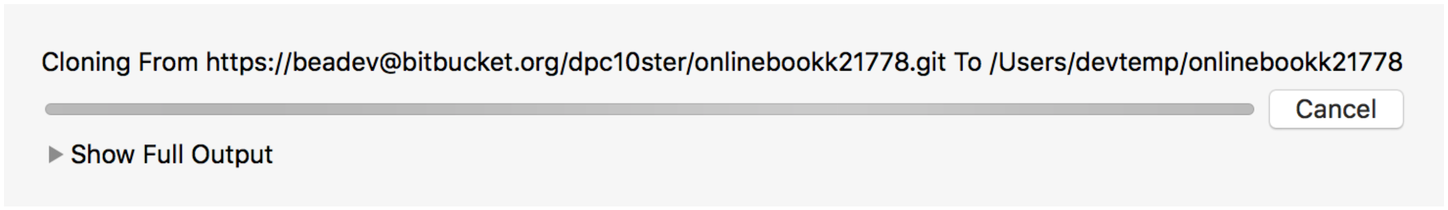
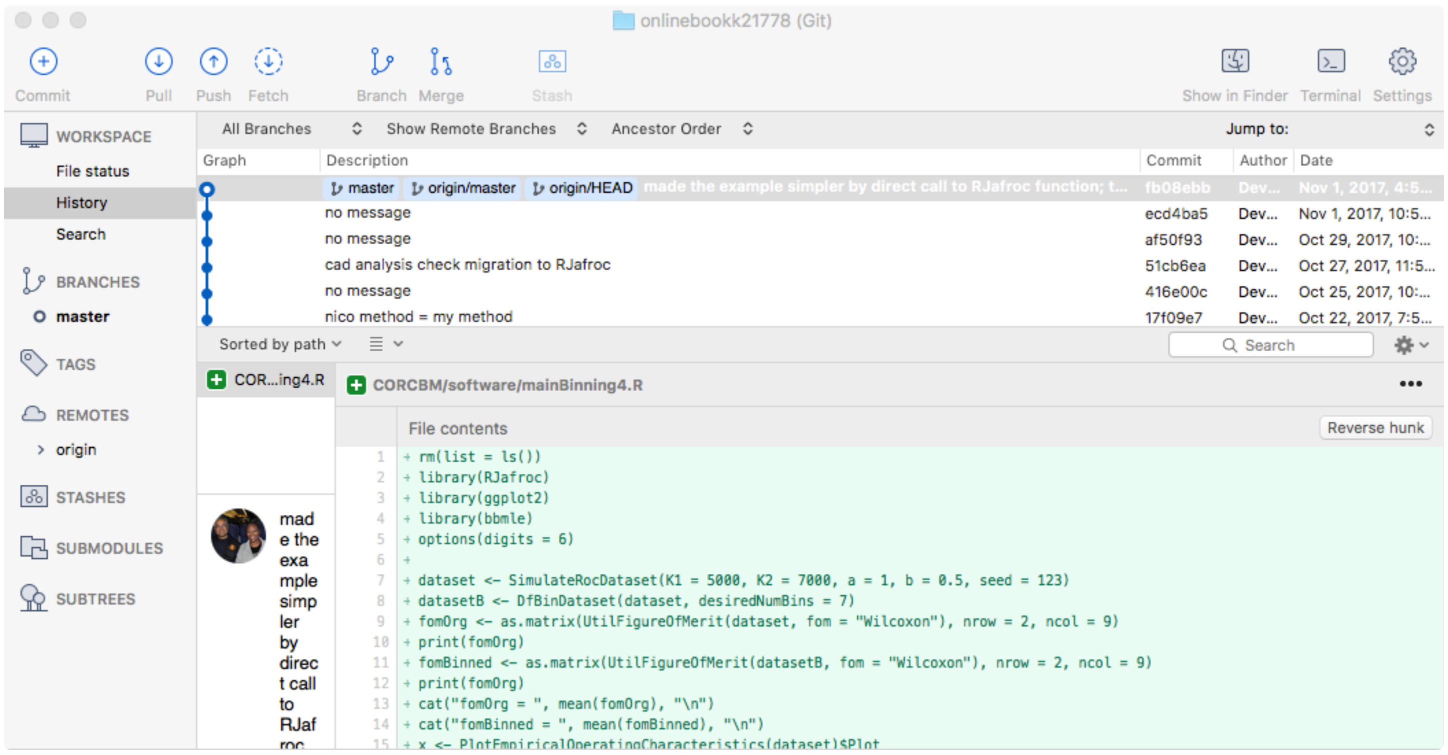

Cloning From https://beadev@bitbucket.org/dpc10ster/onlinebookk21778.git To /Users/devtemp/onlinebookk21778

Figure 14

It may take a while, but finally you should see screens like Figure 15 and Figure 16 (in case you are wondering, "book" has not been misspelled. K21778 is the number assigned to this book by the publisher; also, you may see messages asking if confidential login information should be allowed access by the **`SourceTree`** software; you can safely allow it):



Graph	Description	Commit	Author	Date
	master origin/master origin/HEAD made the example simpler by direct call to RJafroc function; t...	fb08ebb	Dev...	Nov 1, 2017, 4:5...
	no message	ecd4ba5	Dev...	Nov 1, 2017, 10:5...
	no message	af50f93	Dev...	Oct 29, 2017, 10:...
	cad analysis check migration to RJafroc	51cb6ea	Dev...	Oct 27, 2017, 11:5...
	no message	416e00c	Dev...	Oct 25, 2017, 10:...
	nico method = my method	17f09e7	Dev...	Oct 22, 2017, 7:5...

COR...ing4.R

CORCBM/software/mainBinning4.R

made the example simpler by direct call to RJafroc

File contents

```
+ rm(list = ls())
+ library(RJafroc)
+ library(ggplot2)
+ library(bbmle)
+ options(digits = 6)
+
+ dataset <- SimulateRocDataset(K1 = 5000, K2 = 7000, a = 1, b = 0.5, seed = 123)
+ datasetB <- DfBinDataset(dataset, desiredNumBins = 7)
+ fomOrg <- as.matrix(UtilFigureOfMerit(dataset, fom = "Wilcoxon"), nrow = 2, ncol = 9)
+ print(fomOrg)
+ fomBinned <- as.matrix(UtilFigureOfMerit(datasetB, fom = "Wilcoxon"), nrow = 2, ncol = 9)
+ print(fomOrg)
+ cat("fomOrg = ", mean(fomOrg), "\n")
+ cat("fomBinned = ", mean(fomBinned), "\n")
+ x <- PlotEmpiricalOperatingCharacteristics(dataset)$Plot
```

Figure 15

The various lines in the upper panel correspond to commits made by me during the writing of the book and the associated software. For example, the line which says **`nico method = my method`**, dated October 22, 2017, is a commit I made showing that a method of analyzing CAD data used by Prof. Nico Karssemeijer was equivalent to the method described in Chapter 22 of the book.

By simply double clicking on that line you can revert all your files to that date. To get back to the most current date, simply double click on the most recent commit.

Figure 16 is the **`SourceTree`** window showing that a repository **`onlinebookk21778`** has been added.

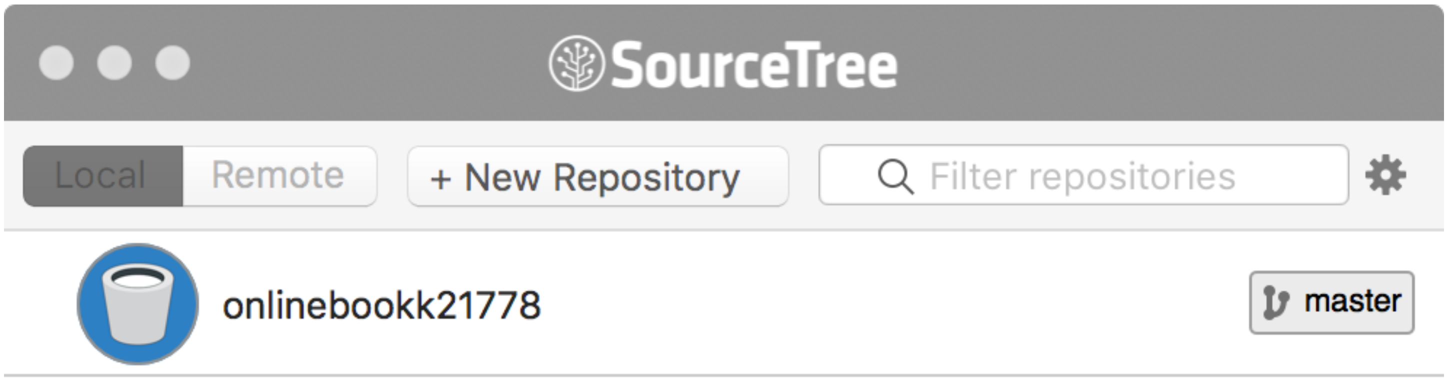


Figure 16

When one or more updates are available, and provided **SourceTree** is running on your machine, you will receive an alert and a number, **1** in the example below, Figure 17, tells you that an update has been posted to the repository and that you may need to synchronize your copy of the files with the most recent ones on the website (just click on **master** and click on **pull** on the next screen). There is much more but this should at least get you started.

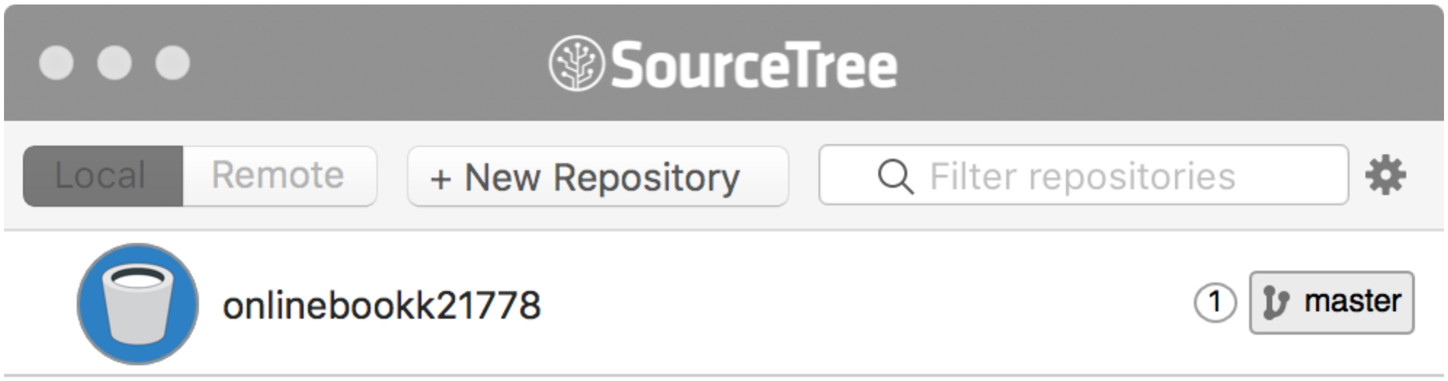


Figure 17

When the files have been synchronized, by clicking on **master** followed by **pull**, the "circled one" symbol will disappear.

So where is the book software?

The files are located in the path named in Figure 9, which happens to be **Users/devtemp/onlinebookk21778** in this example. You may wish to create an alias to this directory on your desktop. Figure 18.

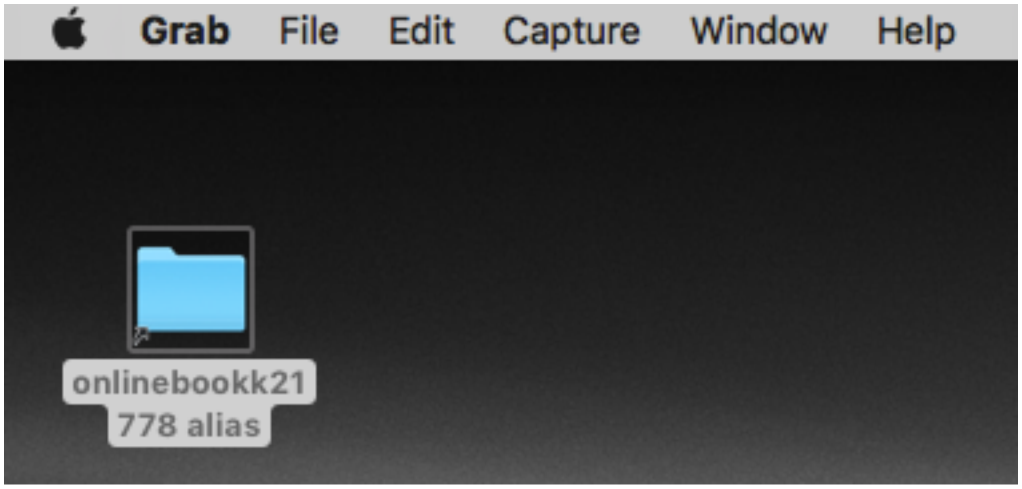
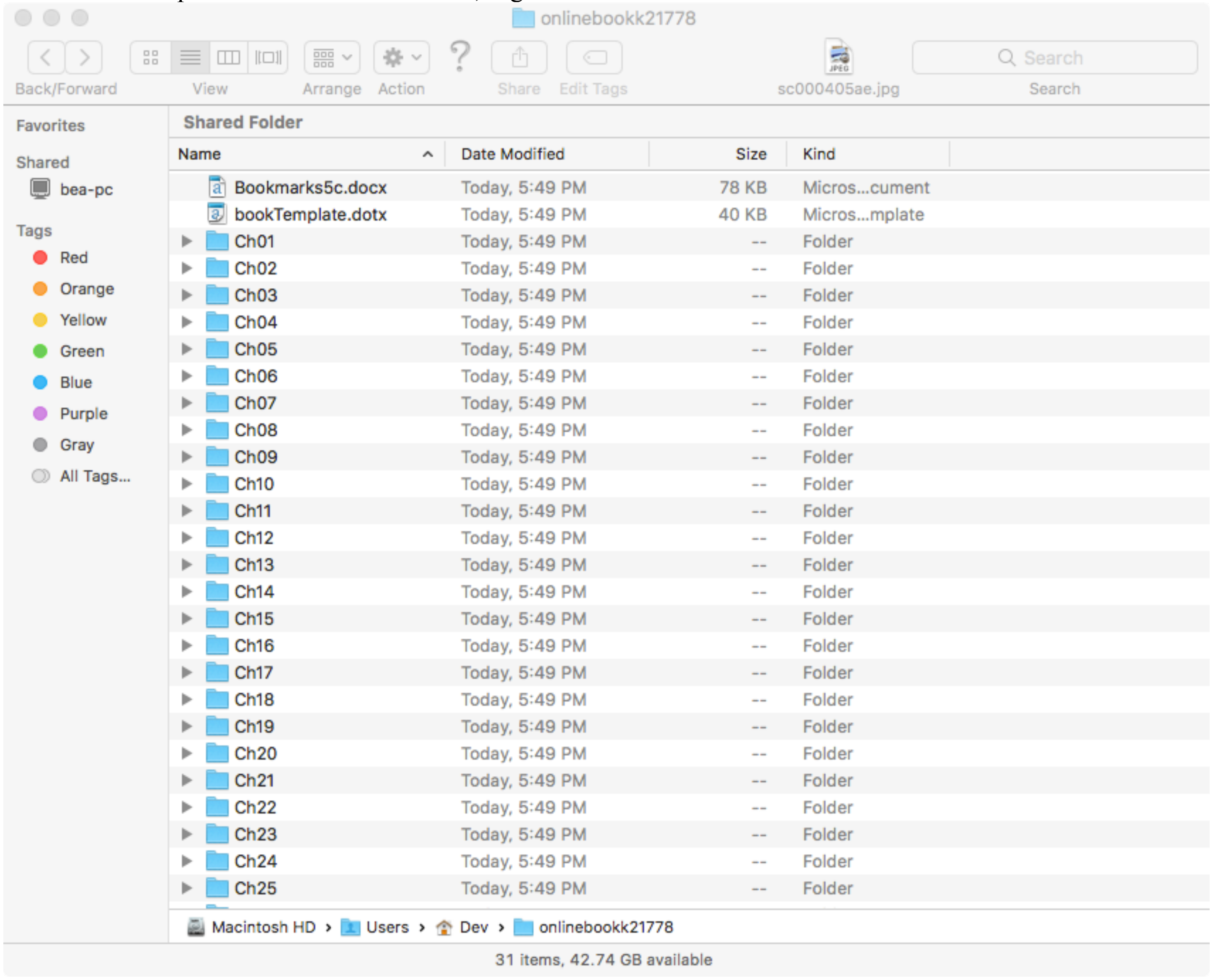


Figure 18

Click the desktop alias to reveal its contents, Figure 19.



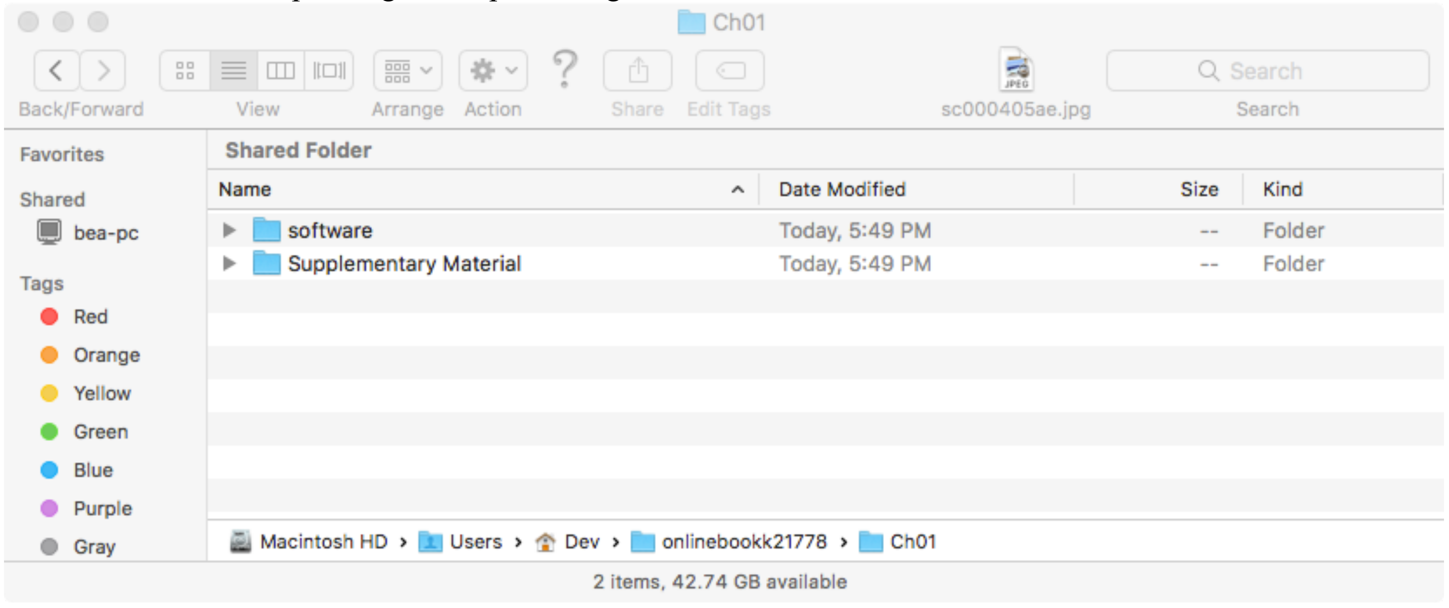
Name	Date Modified	Size	Kind
Bookmarks5c.docx	Today, 5:49 PM	78 KB	Micros...cument
bookTemplate.dotx	Today, 5:49 PM	40 KB	Micros...mplate
Ch01	Today, 5:49 PM	--	Folder
Ch02	Today, 5:49 PM	--	Folder
Ch03	Today, 5:49 PM	--	Folder
Ch04	Today, 5:49 PM	--	Folder
Ch05	Today, 5:49 PM	--	Folder
Ch06	Today, 5:49 PM	--	Folder
Ch07	Today, 5:49 PM	--	Folder
Ch08	Today, 5:49 PM	--	Folder
Ch09	Today, 5:49 PM	--	Folder
Ch10	Today, 5:49 PM	--	Folder
Ch11	Today, 5:49 PM	--	Folder
Ch12	Today, 5:49 PM	--	Folder
Ch13	Today, 5:49 PM	--	Folder
Ch14	Today, 5:49 PM	--	Folder
Ch15	Today, 5:49 PM	--	Folder
Ch16	Today, 5:49 PM	--	Folder
Ch17	Today, 5:49 PM	--	Folder
Ch18	Today, 5:49 PM	--	Folder
Ch19	Today, 5:49 PM	--	Folder
Ch20	Today, 5:49 PM	--	Folder
Ch21	Today, 5:49 PM	--	Folder
Ch22	Today, 5:49 PM	--	Folder
Ch23	Today, 5:49 PM	--	Folder
Ch24	Today, 5:49 PM	--	Folder
Ch25	Today, 5:49 PM	--	Folder

Macintosh HD › Users › Dev › onlinebookk21778

31 items, 42.74 GB available

Figure 19

Click on **Ch01**, corresponding to Chapter 1, Figure 20.



Name	Date Modified	Size	Kind
software	Today, 5:49 PM	--	Folder
Supplementary Material	Today, 5:49 PM	--	Folder

2 items, 42.74 GB available

Figure 20

All chapters have a common structure: a folder containing **software** and a folder containing **Supplementary Material** (the folder may be empty in a few cases, e.g., **Ch02**) In this document we will work with Chapter 1 online material. But first we need to download two important **R** software related items. And this is where the geeky stuff ends and the science begins.

Part 2: Online Appendix 1.A: Introduction to R/RStudio, Part I

Download **R** and the helper software **RStudio**. The code in this book should run on almost any computing environment: e.g., Windows, OSX, Linux, etc.). That is one reason for choosing it. The other reason is that **R** is open source platform, so one has access to the *entire* code; nothing is hidden from the user; with sufficient knowledge one can modify and improve the code; if so, the author would appreciate hearing from the user so that he may incorporate improvements in future versions of the book/code.

Online Appendix 1.A.1: Windows computer

On a Windows PC do a Google search for "**Install R Windows**", and one should be able to find the appropriate link. Download the software and follow the installation instructions. One needs to also install **RStudio** after installing **R**. This too is free software; think of it as a user interface for **R** (**R** already has a basic user interface; **RStudio** adds many powerful features which make life a lot easier). Do a Google search for "**Install RStudio Windows**" and find the link. Download the software and follow the installation instructions.

Online Appendix 1.A.2: OS X (MAC) machine

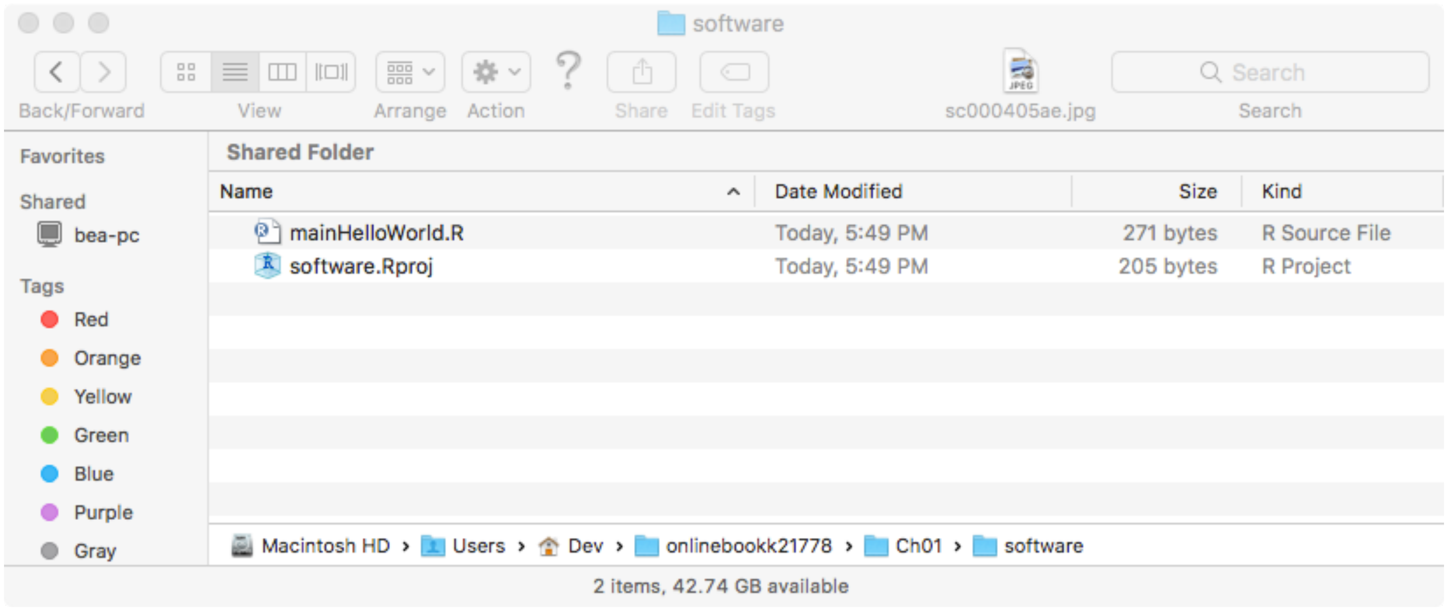
(This is the author's platform.) Search for "**Install R MAC**". Click on the downloaded software and follow the standard OS X installation procedure. After the **R** installation is complete install **RStudio** for the Macintosh operating system. Do a search for "**Install RStudio Mac**" and find the link. Download the software and follow the installation instructions.

Online Appendix 1.A.3: Book software

Feel free to play with the code. Do not worry about "messing it up": if one does "mess up" one can always download the files again. *The author cannot emphasize strongly enough that the only way to really learn is by doing.*

Online Appendix 1.A.4: A simple example using R/RStudio

This section is intended as a gentle introduction to the software. The screen-shots that follow are for the author's iMAC installation (the author's operating system was **`OS X Yosemite 10.10.5`**). If your screen shots look different these are due to differences in platforms (Windows, OSX, Linux, etc.) and version numbers. With a little faith and inquisitiveness one should be able to follow the brief tutorial below. *Follow these directions carefully:* find the folder corresponding to the chapter heading of this chapter and open it; in the author's computer it is **`/Users/devtemp/onlinebookk21778/Ch01`**. You should see a folder named **`software`**: open this folder, Figure 21. [**`devtemp`** is specific to this example; your value would be different]



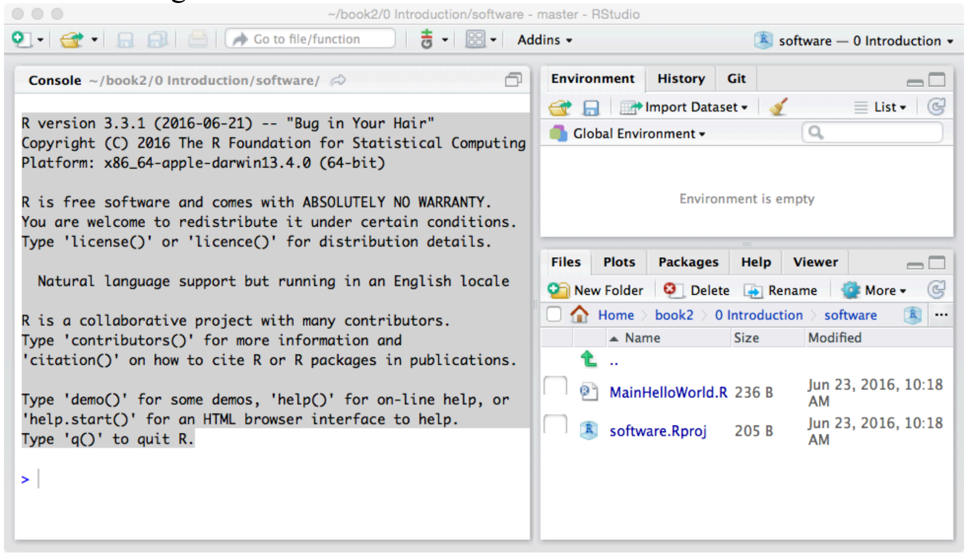
Name	Date Modified	Size	Kind
mainHelloWorld.R	Today, 5:49 PM	271 bytes	R Source File
software.Rproj	Today, 5:49 PM	205 bytes	R Project

Macintosh HD › Users › Dev › onlinebookk21778 › Ch01 › software

2 items, 42.74 GB available

Figure 21

You should see a file named **`software.Rproj`**. The extension means that this is an **`R`** project file. A project file organizes all the files in your project for easy viewing, editing and compilation, but one does not need to know its contents. Open this file by clicking (or double clicking, depending on your computer settings) its icon. Your screen should resemble Figure 22.



```
R version 3.3.1 (2016-06-21) -- "Bug in Your Hair"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin13.4.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> 
```

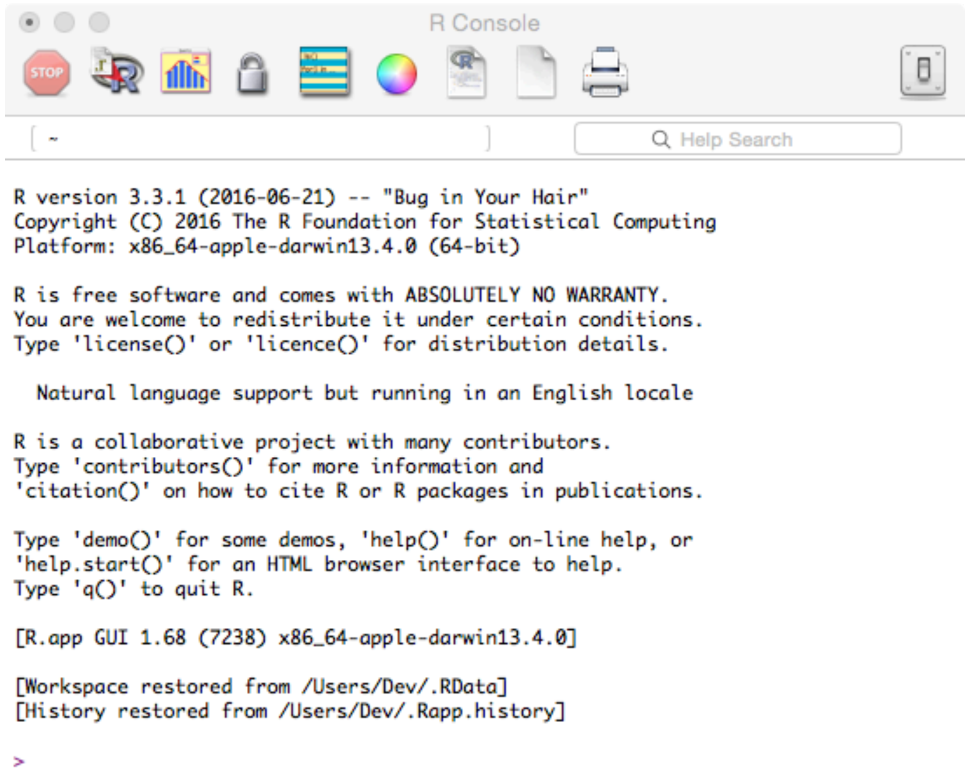
Name	Size	Modified
..		
MainHelloWorld.R	236 B	Jun 23, 2016, 10:18 AM
software.Rproj	205 B	Jun 23, 2016, 10:18 AM

Figure 22

Notice the organization of the display into 3 major panels (one may see 4 panels if any of the source code files - i.e., those ending in **.R**. - are open; simply close all such files to get a display similar, but perhaps not identical to Figure 23). The left panel is labeled **Console** and the right consists of two panels: the top-right panel consists of two sub-panels labeled **Environment, History** and **Git**, and the **Environment** sub-panel is in focus (notice the brighter background of the text **Environment** compared to **History** or **Git**. The bottom-right panel consists of five sub-panels labeled **Files**, **Plots**, **Packages, Help** and **Viewer** and the **Files** sub-panel is in focus (if it is not in focus, click on it to bring it into focus). The actual number of menu items may have changed by the time this book is published, because the developers of **RStudio** and **R** are hard at work improving the software: ignore any extra ones for now.

The left window, termed **Console**, ends with a "**>**" symbol. This is an invitation to the user to enter commands, so this symbol is the command prompt for **R**. Sometimes, when debugging a program, one might see this symbol preceded by a **Browse[2]**, or **Browse[3]**, as in , **Browse[2]>**. This indicates that the software is being run in debug mode. Debugging capabilities have improved dramatically in the author's four-year experience with the **RStudio** software.

The **Console** panel is currently simply showing the output screen one gets from starting **R**. Try it! Locate **R** using **Spotlight** (the magnifying glass symbol in the very top-right of the iMAC display) and open it (i.e., click on it). The **R** application is in the **Applications** folder. This is what I see, Figure 23. [On **Windows** go to **Program** and find the **R** application.]



```
R version 3.3.1 (2016-06-21) -- "Bug in Your Hair"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin13.4.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[R.app GUI 1.68 (7238) x86_64-apple-darwin13.4.0]

[Workspace restored from /Users/Dev/.RData]
[History restored from /Users/Dev/.Rapp.history]

>
```

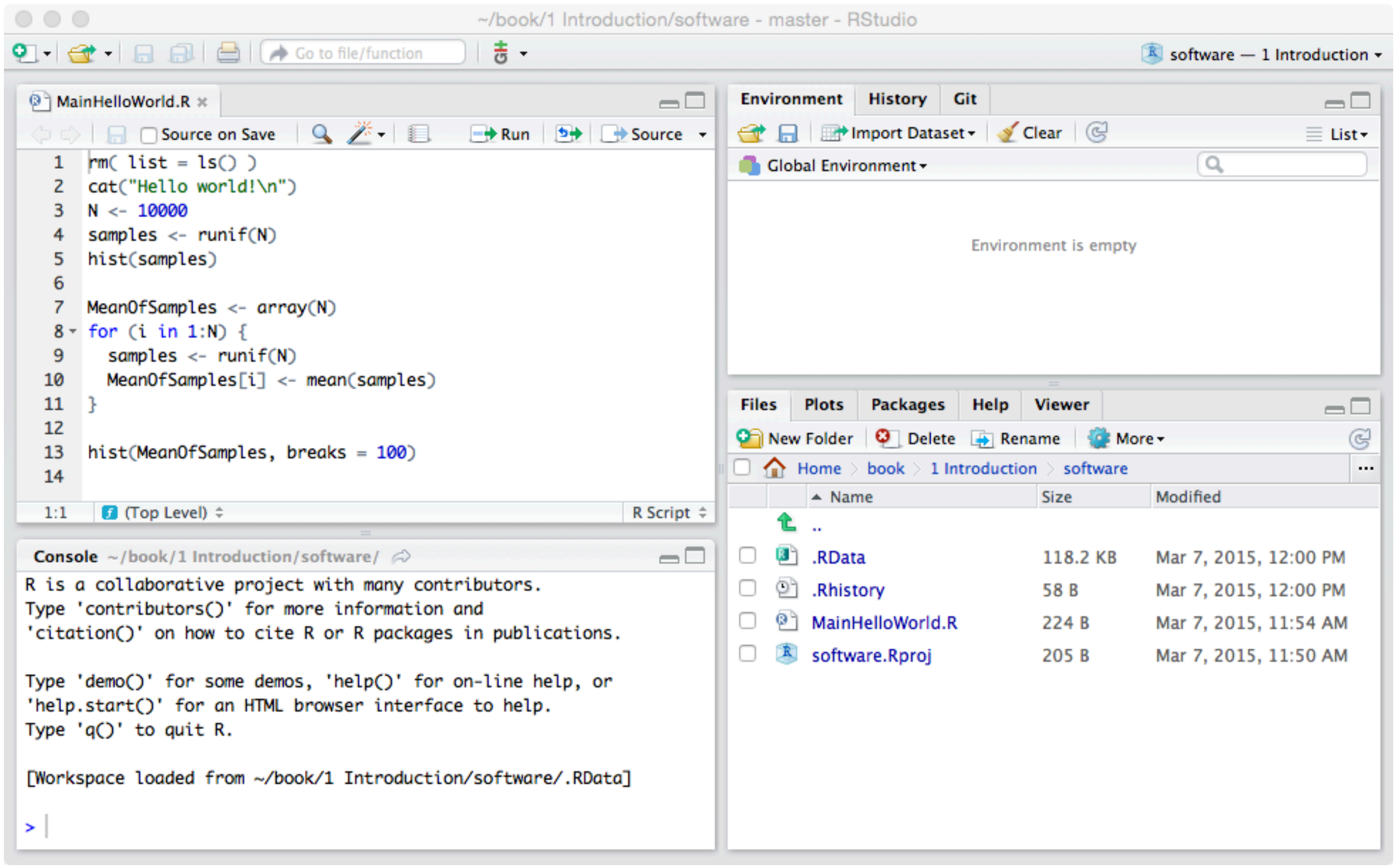
Figure 23

Screen-shot obtained by opening the **R** application (i.e., independent of **RStudio**). Note that it is practically identical to the shaded text in Figure 22. Think of **RStudio** as a helper application that makes it easier to work with **R**, analogous to **SourceTree** making it easier to work with **Bitbucket**. Excepting for the last few lines, the two screens (the left panel of Figure 22 and Figure 23) are identical.

Now quit **R** - in this book we will always use **RStudio** and never open **R** directly.

Returning to Figure 22, the **Files** sub-panel contains all the files in this project. Below the **Files** sub-panel one sees **New Folder**, **Delete**, **Rename** and **More**. The next row shows the complete directory path: **Home/onlinebookk21778/software**. The next row is labeled **Name**, **Size** and **Modified**, clicking on any of which sorts the files according to the chosen label. Click on the file named **mainHelloWorld.R** in this panel.

In this book any file name that starts with ***main*** *contains directly executable code; all the other files with the* ***.R*** *extension are functions (called subroutines in some programming languages) that may be called by directly executable code or by other functions.* This is what I see, Figure 24. Note the additional window showing the code file in addition to the **Console** window. Note the locations of the **Run** and **Source** buttons. The former button executes the line the cursor happens to be on, or a highlighted section of code. The latter executes the entire code in the file.



```
rm( list = ls() )
cat("Hello world!\n")
N <- 10000
samples <- runif(N)
hist(samples)

MeanOfSamples <- array(N)
for (i in 1:N) {
  samples <- runif(N)
  MeanOfSamples[i] <- mean(samples)
}

hist(MeanOfSamples, breaks = 100)
```

```
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Workspace loaded from ~/book/1 Introduction/software/.RData]

> 
```

▲ Name	Size	Modified
..		
.RData	118.2 KB	Mar 7, 2015, 12:00 PM
.Rhistory	58 B	Mar 7, 2015, 12:00 PM
MainHelloWorld.R	224 B	Mar 7, 2015, 11:54 AM
software.Rproj	205 B	Mar 7, 2015, 11:50 AM

Figure 24

Notice the additional **MainHelloWorld.R** window occupying the top-left **RStudio** window, in addition to the **Console** window, which now occupies the bottom-left window. The additional window organizes your *source* code files (also called *script* files, these are all files with the **.R** extension) into one window for convenient viewing and editing; we will refer to it as the "*source*" panel. Whenever one creates new code for this project one should save it to the directory indicated on the bottom-right panel. To distinguish it easily from regular text, all code shown in this book will look like the one shown below (i.e., using the same font type and size, background, shading and borders). A listing of the file **MainHelloWorld.R** follows:

Online Appendix 1.A.5.1 Code Listing

```
rm( list = ls() ) #MainHelloWorld.R
seed <- 1;set.seed(seed)
cat("Hello world!\n")
```

```
N <- 10000
samples <- runif(N)
hist(samples)

MeansOfSamples <- array(N)
for (i in 1:N) {
  samples <- runif(N)
  MeansOfSamples[i] <- mean(samples)
}

hist(MeansOfSamples, breaks = 100)
```

First, notice that the existence of helpful line numbers, generated by **RStudio**, not shown in the above code listing. The hash symbol (**#**) is used in **R** to insert comments: the compiler[3] ignores anything appearing on a line after the hash symbol. This is a convenient way to insert explanations of what we are doing and/or why we are doing it this way. Ignoring the description that follows the hash symbol, the command **rm(list = ls())** on line 1 says (in effect) that we are deleting ("removing") all existing variables so as to start with a "clean slate". It will be shown later how one uses the **Help** system to find out exactly what the code does. Blank lines of code, which are ignored by the compiler, are inserted for improved readability. Multiple commands, separated by semi-colons (**;**) can be put on one line to preserve "vertical real estate". **R** does not have a continuation symbol for long lines - we will see later how to split up long lines across several lines without using any special continuation symbol. Also, **R** commands are case sensitive: as one example, the command **Rm(list = ls())**will not work [Try it! Type **Rm(list = ls())**into the **Console** window (bottom-left panel in Figure 24) and press the **return/enter** key]:

Online Appendix 1.A.5.1.1 Code Snippets

```
> Rm(list = ls())
Error: could not find function "Rm"}
```

Unlike some other programming languages (e.g., **IDL** and **C**), **R** uses the **<-** symbol to *assign the right hand side to the left hand side* (keyboard shortcut: use **Alt-** to enter this quickly in the **Console** window; the shortcut even inserts a space before the value that follows). Line 2 uses the **set.seed()** function to set the seed of the random number generator to unity, to force repeatable "random" sequences[4]. Line 3 uses the **cat()** function, which stands for *concatenate and print*. In the present example the **cat()** function simply prints the string variable **"Hello world!"**. Line 4 initializes the variable **N** to 10,000. Line 5 obtains 10,000 samples from the standard random uniform distribution (i.e., uniformly distributed in the closed range 0 to 1). The function used is called **runif(N)** for "**N** random samples from the random uniform distribution". The 10,000 samples are assigned to the variable **samples**. Line 6 uses the **hist()** function to display a histogram of these samples. Line 8 allocates an **array** variable **MeansOfSamples** to hold 10,000 numbers. The **for**-loop beginning on line 9 and ending on line 12 means, effectively, "repeatedly execute the statements in the enclosed curly brackets for all values of the integer variable **i** in the range 1 to 10,000". On each pass through this loop, at line 10, a fresh sample of **N** random values from the uniform distribution are generated which overwrites the existing variable **samples**, and line 11 uses the **mean()** function to calculate the average of these samples, which is saved to **MeansOfSamples[i]**. The square brackets denote array indexing: the first time through the loop the average is saved to **MeansOfSamples[1]**, the second time it is saved to **MeansOfSamples[2]**, and so on. Unlike **C**, **R** arrays start with 1. Line 14 displays a histogram of the array **MeansOfSamples**. Click on the **Source** button on the top-right corner of the source-file window; clicking this button causes all lines in the current file to be executed sequentially. You should get the following output in the **Console** window:

3 A compiler is software the converts the more-or-less English-like instructions that make some sense to the programmer to sequences of binary instructions that the computer understands, but which would be gibberish to the programmer. When one executes a program, the computer sequentially executes the binary instructions.
4 Allowing the period (**.**) as part of a variable name causes the author to cringe; but in life one cannot have everything one's way.

```
> source(…)
Hello world!
```

The first line **`source(…)`** has been abbreviated as explained in the book, as its contents depend on the installation, which would vary from user to user.

The reassuring message came from line 3. Your **`RStudio plots`** window should look like that shown below:

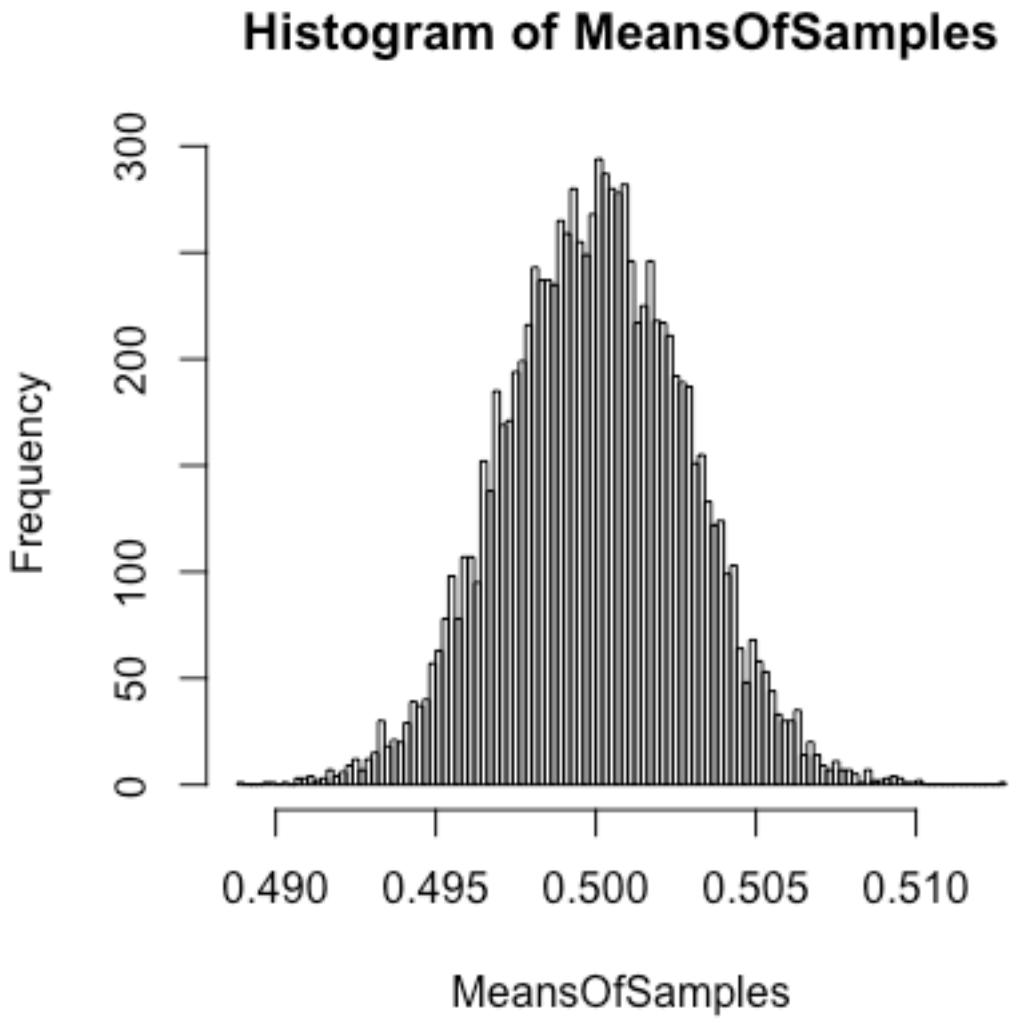
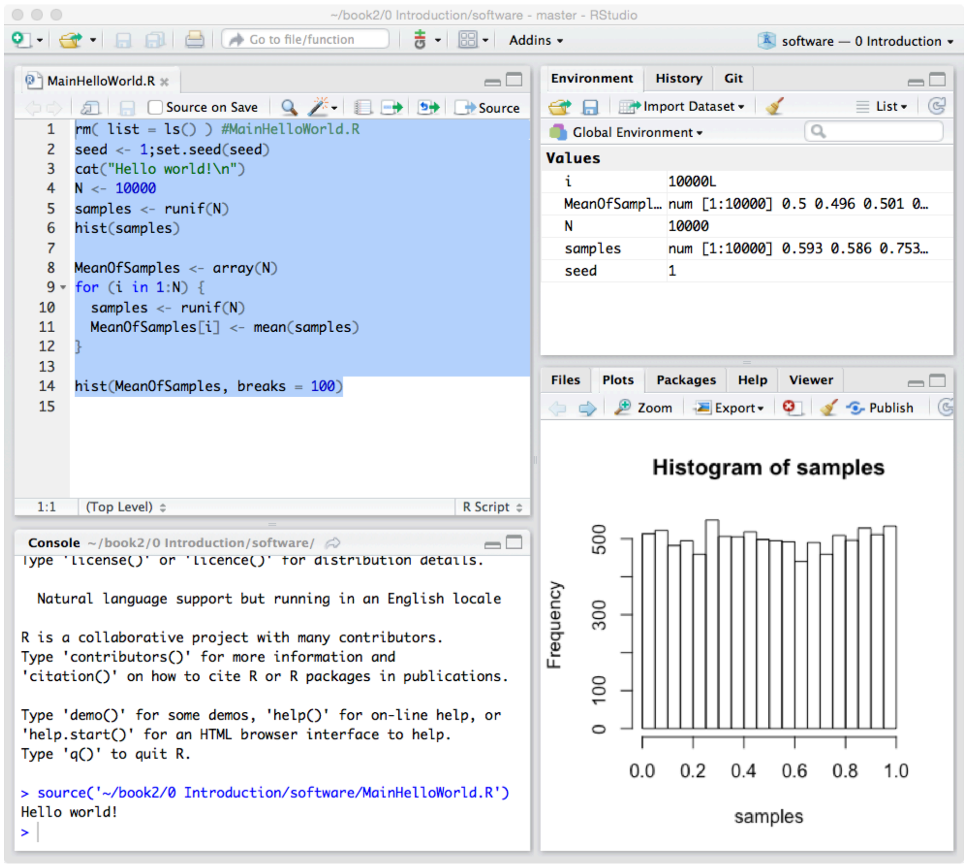


Figure 25
Screen-shot obtained by sourcing the file **`mainHelloWorld.R`**. Note the histogram plot, resulting from line 14.

Notice that the lower-right window is focused on the **`Plots`** tab, and a histogram of the variable **`MeansOfSamples`** is shown, which came from line 14, that looks like a normal distribution centered at 0.5, a result following from the central limit theorem of statistics, which states that the mean of a sufficiently large number of independent random samples, will be approximately normally distributed, regardless of the underlying distribution.

Notice that the top-right window is focused on the **`Environment`** tab, which is filled in with values (later we will demonstrate many uses for this window, basically a convenient way of examining variables without having to print them out). For example, one sees that **`i`** is 10,000 (the last value in the **`for`** loop), **`MeansOfSamples`** is an array with 10,000 values the first few are 0.5, 0.496, 0.501, 0.504, etc. all values being near 0.5. The variable **N** is 10,000 (from line 4) and finally the variable **samples** is an array with 10,000 values, the first few being 0.593, 0.586, 0.753, 0.964, etc., which correspond to the last execution of line 10.

If one looks carefully at the top-left end of the **Plots** window one sees that the blue *left* arrow button is active, indicating that there is another plot *hiding* behind the one being shown; clicking on this button Clicking on the blue *left* arrow should yield the following screen-shot, Figure 26.



```
1   rm( list = ls() ) #MainHelloWorld.R
2   seed <- 1;set.seed(seed)
3   cat("Hello world!\n")
4   N <- 10000
5   samples <- runif(N)
6   hist(samples)
7
8   MeanOfSamples <- array(N)
9   for (i in 1:N) {
10    samples <- runif(N)
11    MeanOfSamples[i] <- mean(samples)
12  }
13
14  hist(MeanOfSamples, breaks = 100)
15
```

```
Values
  i               10000L
  MeanOfSampl…    num [1:10000] 0.5 0.496 0.501 0…
  N               10000
  samples         num [1:10000] 0.593 0.586 0.753…
  seed            1
```

```
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> source('~/book2/0 Introduction/software/MainHelloWorld.R')
Hello world!
>
```

Figure 26

The histogram, which is due to line 6, is nearly flat, as one expects with a uniform distribution. This time the *right* blue arrow is active, clicking on which will bring up the previous figure. So one can switch between all the plots (not just two) generated by one's code. Click on the **Clear All** (with the "broom" symbol next to it) to delete all plots.

This ends the first tutorial. But before moving on, look at the **Supplementary Material** folder. It contains this document and a **pdf** file giving an overview of the **R** programming language.