

Statistics 360: Advanced R for Data Science

Lecture 6

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Debugging

Measuring performance

Debugging (Ch22) and Measuring performance (Ch 23)

- ▶ Reading: Text, Chapters 22 and 23
- ▶ Topics on debugging:
 - ▶ overview of debugging
 - ▶ tracing execution with `traceback()`
 - ▶ interactive debugging with `debug()` and `browser()`
 - ▶ non-interactive debugging: `dump.frames()` and printing
 - ▶ test cases to detect future bugs
- ▶ Topics on measuring performance:
 - ▶ profiling
 - ▶ microbenchmarking
 - ▶ final thoughts

Debugging

Overview

- ▶ Focus on the easy part of debugging: finding and fixing the source of unexpected errors.
 - ▶ Mistakes that give incorrect results but throw no errors are harder to find.
- ▶ Workflow tips for finding and fixing errors
 - ▶ Google it: If you don't understand the error message, try pasting it into a google search.
 - ▶ Make a small self-contained example (reproducible example, a.k.a. `reprex`).
 - ▶ Find it with tools like `traceback()`, `debug()` and `browser()`.
 - ▶ Fix it and make a test case to alert you if you accidentally re-introduce the bug.

Reproducible examples

- ▶ Reproducible means including any source code, data and library calls so that the code can run as it did when the error was triggered.
- ▶ Next reduce the code to a minimal example that triggers the problem.
 - ▶ For example, remove lines of code, compute on a smaller R object, use built-in data.
- ▶ The act of creating the reprex may show you the error.
- ▶ If not, you are in a position to ask for help from a class-mate, mailing list or stack overflow.
- ▶ I find it hard to construct reprexs without first finding the lines that throw the error ...

Tracing execution

- ▶ After an error, you can use `traceback()` to see the sequence of function calls (“call stack”) that lead to the error.
 - ▶ The numbers appended to each entry are the line numbers of the function call in the (parent) calling function, but they usually just confuse me ...

```
f <- function(x) { g(h(x)) }
g <- function(x) {
  x
}
h <- function(x) {
  if(!is.numeric(x)) stop("x must be numeric")
}
#f("cat") # uncomment to run
#traceback()

#> f("cat")
#Error in h(x) : x must be numeric
#> traceback()
#4: stop("x must be numeric") at #2
#3: h(x) at #2
#2: g(h(x)) at #1
#1: f("cat")
```

Interactive debugging

- ▶ Main tools are `browser()` and `debug()`.
- ▶ Stop and step through function execution.
 - ▶ Can print variables and execute R commands to investigate

```
h <- function(x) {  
  browser()  
  if(!is.numeric(x)) stop("x must be numeric")  
}  
#f("cat")
```


browser commands

- ▶ `n` executes the next step. Use `print(n)` to print a variable named `n`.
- ▶ `s` is like `n` but will step into a function call.
- ▶ `f` finishes execution of the current loop or function.
- ▶ `c` leaves interactive debugging and continues regular execution.
- ▶ Enter (Return) repeats the last browser command
- ▶ `Q` completely exits the function.

debug()

```
h <- function(x) {  
  if(!is.numeric(x)) stop("x must be numeric")  
}  
  
#debug(f)  
#f("cat")  
#undebug(f)  
# debug(g)  
# f("cat")  
# undebug(g)  
# debug(h)  
# f("cat")  
# undebug(h)
```

Non-interactive debugging

- ▶ You can insert `print()` or `cat()` statements to see values of variables in your code if you find the trace too confusing and browser too time-consuming.

Test cases

- ▶ After you find and fix a bug it is a good idea to devise a test of your code that will flag the problem if you ever accidentally re-introduce it.
- ▶ If you are writing an R package you should investigate the `testthat` package, which helps you compile and run “unit” tests on small pieces of your code.

```
f <- function(x) { x + 3 }  
# test  
f(3) # should return 6
```

```
## [1] 6
```

Measuring performance

Measuring performance

- ▶ When you write code you develop an intuition about what parts will run slowly – don't trust this!
- ▶ As statisticians we know that the only thing you can trust is data.
- ▶ Profiling and benchmarking are ways to collect data on your code

```
library(profvis) #visualize profiling data  
library(bench)  # benchmarking tools
```

Profiling

- ▶ R uses a statistical profiler that records the call stack at small intervals.
 - ▶ Read the call stack from right to left

```
f <- function() {pause(0.1);g();h()} # pause() is from profvis
g <- function() {pause(0.1);h()}
h <- function() {pause(0.1)}
Rprof()
f()
```

```
## NULL
```

```
Rprof(NULL) # Now view Rprof.out
```

```
sample.interval=20000
```

```
"pause" "f"
```

```
"pause" "f"
```

```
"pause" "f"
```

```
"pause" "f"
```

```
"pause" "f"
```

```
"pause" "g" "f"
```

```
"pause" "g" "f"
```

```
"pause" "g" "f"
```

```
"pause" "g" "f"
```

```
"pause" "g" "f"
```

```
"pause" "h" "g" "f"
```

```
"pause" "h" "g" "f"
```

```
"pause" "h" "g" "f"
```

```
"pause" "h" "g" "f"
```

```
"pause" "h" "g" "f"
```

```
"pause" "h" "f"
```

```
"pause" "h" "f"
```

```
"pause" "h" "f"
```

```
"pause" "h" "f"
```

```
"pause" "h" "f"
```


Summary of profile

```
# summaryRprof() # uncomment and run
```

Visualize profile

- ▶ `profvis()` gives a nicer summary of the profiling.
- ▶ Two panels:
 - ▶ top shows the source code with graphs depicting memory use and execution time
 - ▶ bottom is a “flame graph” showing the call stack, read bottom to top

```
# profiler will refer to this source file  
source("lec6profiling.R")  
# Or choose Profile from RStudio  
# profvis({ f() })
```

Memory profiling

- ▶ The `profvis()` output also includes information about memory usage.
- ▶ Illustrate with an example from the week 2 exercises where we built a dataset of 500×1000 observations.
 - ▶ included in source file `lec6profiling.R`

```
# profvis({ bigd1() })  
# profvis({ bigd2() })  
# profvis({ bigd3() })
```

Notes on memory profiling

- ▶ The grey bars in the bar and flame graphs show memory being freed by the garbage collector (notice the <GC> when you hover over the grey bars in the flamegraph).
- ▶ Memory claiming and freeing in `bigd1` > `bigd2` > `bigd3`.

Microbenchmarking

- ▶ We have done benchmarking on `bigd1/2/3` with `system.time()`.
- ▶ For small chunks of code that take less time, `system.time()` is less useful.
- ▶ Microbenchmarking measures performance of code chunks that run in very small time increments.
- ▶ To do this, the `bench` package uses a high precision timer.

bench

- ▶ Times the expression in multiple runs.
 - ▶ At least one run and at most the number of runs it can do in 1/2 sec.
- ▶ Output displayed as a summary table or graph.

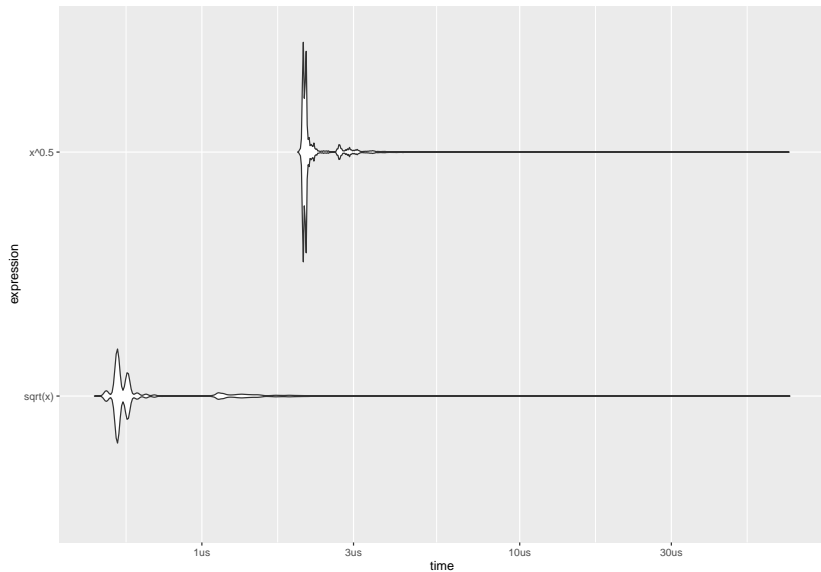
```
library(bench)
x <- runif(100)
lb <- mark(
  sqrt(x),
  x ^ 0.5
)
lb
```

```
## # A tibble: 2 x 6
##   expression      min    median `itr/sec` mem_alloc `gc/sec`
##   <bch:expr> <bch:tm> <bch:tm>    <dbl> <bch:byt>    <dbl>
## 1 sqrt(x)      459ns    542ns  1271674.    848B         0
## 2 x^0.5         2us    2.12us   432515.    848B         0
```

- ▶ ns = nanosecond = one billionth of a second = $1/10^9$ of a second.
- ▶ us = μ s = microsecond = one millionth of a second
- ▶ ms = millisecond = one thousandth of one second

```
plot(lb,type="violin")
```

```
## Loading required namespace: tidyr
```



Interpretation

- ▶ Time units in the output table can be in microseconds, nanoseconds, ...
- ▶ Run-time summary statistics include min, mean, median, max, and itr/sec.
- ▶ `mem_alloc` and `gc/sec` related to memory usage
- ▶ There are other columns in the output not shown – see `?mark` for details.
- ▶ The bumps in the violin plot may indicate that your computer was doing something else during some of the runs
- ▶ Notice the highly skewed distribution – median is more useful than mean

Final thoughts

- ▶ Avoid the temptation to let performance considerations dominate your code development and lead you to profile and benchmark extensively.
- ▶ Remember that the most important performance improvement is code that gives the right answer.