Computational Skills for Biostatistics I: Lecture 2

Amy Willis, Biostatistics, UW

October 5, 2017

Housekeeping

- The high bar for Homework 1 was met
- Individual comments coming soon via Github Classroom

Pop quiz

What is the distribution of the median of 51 exponentially-distributed random variables with rate $= 1$?

Pop quiz

What is the distribution of the median of 51 exponentially-distributed random variables with rate $= 1$?

- No idea? Me neither!
- How could we use computing power to help us?

Avoiding math with computers

To understand the distribution of the median of 51 exponentially-distributed random variables with rate $= 1$, we can

- Draw 51 Exp(1) random variables, calculate their median
- Do this again, and again, and again...

We can use the collection of medians to calculate summary statistics, draw histograms, do hypothesis testing...

Avoiding math with computers...

... and learning how to write loops in the process

```
simulations <- 10000
many_medians <- rep(NA, simulations)
set.seed(171005)
for (i in 1:simulations) {
  my_sample <- rexp(n = 51, rate = 1)
  many_medians[i] <- median(my_sample)
}
```

Avoiding math with computers

```
mean(many_medians) # actually: 0.70286
```

```
## [1] 0.7012355
```

```
var(many_medians) # actually: 0.01978
```

```
## [1] 0.01985761
```

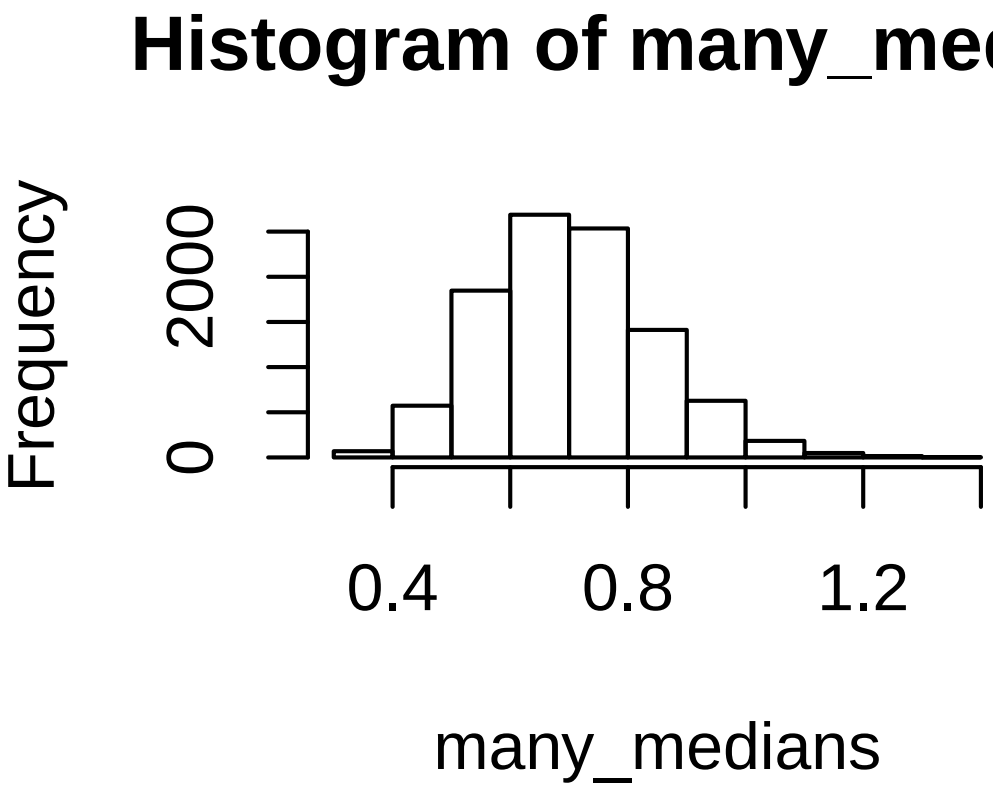
We just calculated the moments of an intractable distribution using computing!

Avoiding math with computers

We could work out almost anything about the sample median in this way!

The distribution of the median of 51 Exp(1) random variables:

```
hist(many_medians)
```



Reproducible simulations

```
set.seed(9)
rexp(4)
```

```
## [1] 1.403092 1.479229 1.255778 1.170410
```

```
rexp(4)
```

```
## [1] 0.337385913 0.005871764 0.897366012 0.971816242
```

```
set.seed(9)
rexp(4)
```

```
## [1] 1.403092 1.479229 1.255778 1.170410
```

A note on history

A note on history

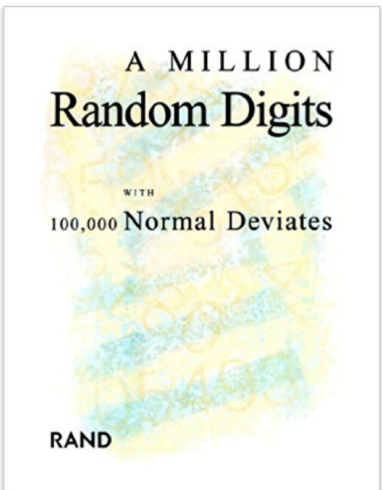
Books › Science & Math › Mathematics

A Million Random Digits with 100,000 Normal Deviates 0th Edition

by The RAND Corporation (Author)

680 customer reviews

Look inside



ISBN-13: 978-0833030474
ISBN-10: 0833030477
Why is ISBN important?

Sell yours for a Gift Card
We'll buy it for $17.57

Hardcover
$174.95

Paperback
$50.27 - $64.60

Other Sellers
See all 4 versions

Buy used $50.27

Buy new prime **$64.60**

In Stock.
Ships from and sold by Amazon.com. Gift-wrap available.
FREE Shipping for Prime members Details
Note: Available at a lower price from other sellers, potentially without free Prime shipping.

Want it Friday, Oct. 6? Order within **15 hrs 17 mins** and choose **One-Day Shipping** at checkout.
Details

List Price: $68.00 Save: $3.40 (5%)
8 New from $60.54
Qty: 1
Add to Cart
Turn on 1-Click ordering
Ship to:
Amy Willis- Seattle - 98115

More Buying Choices
8 New from $60.54 | 13 Used from $50.27
21 used & new from $50.27
See All Buying Options

Possibly containing errors?

Customer reviews

680

4.0 out of 5 stars

5 star	55%
4 star	16%
3 star	10%
2 star	5%
1 star	14%

See all verified purchase reviews

Share your thoughts with other customers

Write a customer review

Rated by customers interested in

What's this?

Math Books	Computer Books	Sports Books
4.5 out of 5 stars	4.1 out of 5 stars	3.7 out of 5 stars

Is this feature helpful? Yes No

Top customer reviews

Random? It lists almost 600 integers in numerical order!

By Obi Wan TOP 100 REVIEWER on January 27, 2015

Format: Paperback

I was duped by the title of this book. It is supposed to be about random digits. And at first glance you do see randomness.

But after reading the book a while I started seeing a pattern. I did extensive research to prove my theory. After hours of mathematical modeling I conclusively proved that there is a set of numbers in this book that it not only a pattern, but is outright sequential!

The top corner of each page (left corner on the left side pages, right corner of the right side pages) was a list of sequential numbers from 1 to 628, all in a row. No numbers are skipped. Even the prime numbers are included! At first you don't notice this because there is only 1 number on each page. But as you advance through the book you notice that the numbers keep advancing by 1 every time you turn the page.

3 comments | 67 people found this helpful. Was this review helpful to you? Yes No Report abuse

Difficult to follow

★★☆☆☆ **Too unpredictable**

By pontifex on January 24, 2011

Format: Paperback

The book is too hard to follow, the author randomly shifts from one number to another without any prior warning.

1 comment | 412 people found this helpful. Was this review helpful to you? Yes No Report abuse

Better just buy a sudoku book

★★★☆☆ **Weirdest sudoku book ever**
By John Peter O'connor on October 6, 2012
Format: Paperback

This has got to be the most useless set of sudoku puzzles ever.

In my copy of the book, all of the puzzles were already filled in which I find really annoying and what is worse, most of them have been filled in wrongly.

I have been through the whole book really carefully and only found seven puzzles that had been filled out correctly! Yes, just seven.

Well, making the best of a bad job, I am now going through the book trying to correct all of the faulty puzzles and I will then submit my corrections.

Perhaps a second edition will be more useful.

I did find last week's winning lottery numbers on page 18 though.

Comment | 139 people found this helpful. Was this review helpful to you? Yes No Report abuse

★☆☆☆☆ **Not really random**
By TDB on September 26, 2012
Format: Paperback

I bought two copies of this book. I find that the first copy perfectly predicts what the numbers will be in the second copy. I feel cheated.

Structure of a for loop

`for()` loops are not terrible, but watch out:

- First make an empty object of the correct dimension (e.g. vector, matrix, data frame) and *then* fill it in
- Don't forget to store the output of each iteration!
- For large loops and objects, growing the output is a big slowdown
  - This is because of the way that memory is handled in R

A special set up

The only use of the index `i` was for storage.

```
simulations <- 10000
many_medians <- rep(NA, simulations)
set.seed(171005)
for (i in 1:simulations) {
  my_sample <- rexp(n = 51, rate = 1)
  many_medians[i] <- median(my_sample)
}
```

A special set up

Since we are merely doing the same thing again and again, let's use a new function to take care of all of the admin

```
set.seed(171005)
many_medians <- replicate(simulations,
                          median(rexp(n = 51, rate = 1)))
```

The second argument to `replicate()` is the expression you want replicated

Loop indices

The index of our loop (`i`) does not need to be a vector

```
str(airquality) # a built-in dataset
```

```
## 'data.frame':    153 obs. of  6 variables:
##  $ Ozone  : int  41 36 12 18 NA 28 23 19 8 NA ...
##  $ Solar.R: int  190 118 149 313 NA NA 299 99 19 194 ...
##  $ Wind   : num  7.4 8 12.6 11.5 14.3 14.9 8.6 13.8 20.1
##  $ Temp   : int  67 72 74 62 56 66 65 59 61 69 ...
##  $ Month  : int  5 5 5 5 5 5 5 5 5 5 ...
##  $ Day    : int  1 2 3 4 5 6 7 8 9 10 ...
```

Loop indices

The index of our loop (`i`) does not need to be a vector

```
for (month in unique(airquality$Month)) {
  print(mean(airquality$Ozone[airquality$Month == month],
             na.rm = TRUE)) # prints but doesn't store
}
```

```
## [1] 23.61538
## [1] 29.44444
## [1] 59.11538
## [1] 59.96154
## [1] 31.44828
```

Loop indices

A better way using by()

```
by(airquality$Ozone, list(month = airquality$Month),
   mean, na.rm = TRUE)
```

```
## month: 5
## [1] 23.61538
## ------------------------------------------------------------
## month: 6
## [1] 29.44444
## ------------------------------------------------------------
## month: 7
## [1] 59.11538
## ------------------------------------------------------------
## month: 8
## [1] 59.96154
## ------------------------------------------------------------
## month: 9
## [1] 31.44828
```

- "Break the data into subsets by month, then calculate the mean Ozone level for each month, omitting missing values"

Looping over subsets: by()

```
by(airquality$Ozone, list(month = airquality$Month),
   mean, na.rm = TRUE)
```

- First argument (data): variable to be analysed
- Second argument (INDICES): list of subsets. Could be multiple variables: `list(month = airquality$Month, toohot = airquality$Temp > 85)`
- Third argument (FUN) is the analysis function to use on the subsets
- Any other arguments (e.g. `na.rm=TRUE`) are used as additional arguments to the analysis function

Looping over subsets: by()

- Output is an object of class by, which has its own print method, print.by()
- The implementation of print for objects of class by is kind of annoying: use unclass() to get rid of it

```
ozone_summary <- by(airquality$Ozone,
                    list(month = airquality$Month),
                    mean, na.rm = TRUE)
unclass(ozone_summary) # one option
```

```
## month
##        5        6        7        8        9
## 23.61538 29.44444 59.11538 59.96154 31.44828
## attr(,"call")
## by.default(data = airquality$Ozone, INDICES = list(month
##     FUN = mean, na.rm = TRUE)
```

Looping over variables: apply()

```
apply(X=airquality, MARGIN=2, FUN=mean, na.rm=TRUE)
```

```
##       Ozone     Solar.R        Wind        Temp       Month
##   42.129310 185.931507    9.957516   77.882353    6.993464
```

- X: an array, usually a matrix or data frame
- MARGIN: the direction. MARGIN = 1 applies the function to each row, MARGIN = 2 applies the function to each column.
- FUN: the function to be applied
- Any other arguments to be passed to FUN

Looking over variables: `apply()`

Ad-hoc functions can be defined inline:

```
apply(airquality, 2,
      function(x) { c(mean = mean(x, na.rm = TRUE),
                      sd = sd(x, na.rm = TRUE))})
```

```
##          Ozone   Solar.R     Wind     Temp    Month
## mean 42.12931 185.93151 9.957516 77.88235 6.993464 15.80
## sd   32.98788  90.05842 3.523001  9.46527 1.416522  8.86
```

(but it's generally better to define them externally)

Passing arguments through to other functions

```
mean_and_sd <- function(x, ...) { c(mean = mean(x, ...),
                                    sd = sd(x, ...)) }
apply(airquality, 2, mean_and_sd, na.rm = TRUE)
```

```
##          Ozone   Solar.R     Wind     Temp    Month
## mean 42.12931 185.93151 9.957516 77.88235 6.993464 15.8
## sd   32.98788  90.05842 3.523001  9.46527 1.416522  8.8
```

Debugging code with ellipses can be tricky! Be cautious...

by()-ing more

Applying our own functions using by()

```
by(airquality, list(toohot = airquality$Temp > 85),
   function(subset) { round(apply(subset, 2, mean_and_sd),
                            digits = 2) })
```

```
## toohot: FALSE
##       Ozone Solar.R  Wind  Temp Month   Day
## mean     NA      NA 10.59 74.50  6.83 16.30
## sd       NA      NA  3.41  7.78  1.49  8.58
## ------------------------------------------------------------
## toohot: TRUE
##       Ozone Solar.R Wind  Temp Month   Day
## mean     NA      NA 7.73 89.74  7.56 14.06
## sd       NA      NA 3.01  3.18  0.93  9.74
```

git

- To download all new material to your local copy, go to your materials folder and type `git pull`
  - This will give you lecture 2 and homework 2
- The standard workflow for adding a new file or updating an old one

```
git pull
git add homework2-response.pdf
git commit -a -m 'question 2 part b response'
git push
```

- You must have a git repository set up already to do this (e.g. with `git init` or `git clone ...`)

Coming soon

- Homework 2 due next Thursday at 2 p.m.
  - Submission via github classroom
  - Same instructions as homework 1 – but don't overwrite homework 1!
- Homework 1 feedback coming soon
- Next week: pipe operators!