



THE ART OF PROGRAMING

Writing clear code

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Basic principles

- ▶ **Code that works**

 - No bugs; efficiency is secondary (or tertiary)

- ▶ **Readable**

 - Fixable; extendible

- ▶ **Reusable**

 - Modular; reasonably general

- ▶ **Reproducible**

 - Re-runnable

- ▶ **Think before you code**

 - More thought \implies fewer bugs/re-writes

- ▶ **Learn from others' code**

 - R itself; key R packages

Write programs for people, not computers

Wilson et al. (2014) PLoS Biol 12:e1001745

Write functions

```
fac2num <-  
function(x)  
{  
  nam <- names(x)  
  x <- as.numeric(as.character(x))  
  names(x) <- nam  
  x  
}
```

Another example

```
# rmvn: simulate from multivariate normal distribution
rmvn <-
function(n, mu=0, V=diag(rep(1, length(mu))))
{
  p <- length(mu)

  if(any(dim(V) != p))
    stop("Dimension problem!")

  D <- chol(V)

  matrix(rnorm(n*p),ncol=p) %*% D + rep(mu,each=n)
}
```

Further examples

```
# colors from blue to red
revrainbow <-
function(n=256, ...)
  rev(rainbow(start=0, end=2/3, n=n, ...))

# move values above/below quantiles to those quantiles
winsorize <-
function(vec, q=0.006)
{
  lohi <- quantile(vec, c(q, 1-q), na.rm=TRUE)
  if(diff(lohi) < 0)
    lohi <- rev(lohi)

  vec[!is.na(vec) & vec < lohi[1]] <- lohi[1]
  vec[!is.na(vec) & vec > lohi[2]] <- lohi[2]

  vec
}
```

Writing functions

- ▶ Break large tasks into small units.
 - Make each discrete unit a function.
- ▶ If you write the same code more than once, **make it a function.**
- ▶ If a line/block of code is complicated, **make it a function.**

Don't repeat yourself (or others)

- ▶ Avoid having repeated blocks of code.
- ▶ Create functions, and call those functions repeatedly.
- ▶ This is easier to maintain.
 - If something needs to be fixed/revised, you just have to do it the one time.
- ▶ Look at others' libraries/packages.
 - Don't write what others have already written (especially if they've done it better than you would have).

Don't make things too specific

- ▶ Write code that is a bit more general than your specific data
 - Don't assume particular data dimensions.
 - Don't forget about the possibility of missing values (even if **your** data doesn't have any).
 - Aim for re-use.
- ▶ Use function arguments
 - Don't assume particular data file names
 - Don't hard-code tuning parameters
 - R scripts can take **command-line arguments**:

```
Rscript myscript.R input_file  
output_file  
args <- commandArgs(TRUE)
```

No global variables, ever!

- ▶ Don't refer directly to objects in your workspace.
- ▶ If a function needs something, pass it as an argument.
- ▶ (But what about really big data sets?)

No magic numbers

- ▶ Name numbers and use the names

```
max_iter <- 1000  
tol_convergence <- 0.0001
```

- ▶ **Even better:** include them as function arguments

Indent!

```
# move values above/below quantiles to those quantiles
winsorize <-
function(vec, q=0.006)
{
  lohi <- quantile(vec, c(q, 1-q), na.rm=TRUE)
  if(diff(lohi) < 0)
  lohi <- rev(lohi)
  vec[!is.na(vec) & vec < lohi[1]] <- lohi[1]
  vec[!is.na(vec) & vec > lohi[2]] <- lohi[2]
  vec
}
```

Use white space

```
# move values above/below quantiles to those quantiles
winsorize<-function(vec,q=0.006)
{lohi<-quantile(vec,c(q,1-q),na.rm=TRUE)
if(diff(lohi)<0)lohi<-rev(lohi)
vec[!is.na(vec)&vec<lohi[1]]<-lohi[1]
vec[!is.na(vec)&vec>lohi[2]]<-lohi[2]
vec}
```

Don't let lines get too long

```
get_grid_index <-  
function(vec, step)  
{  
  grid <- seq(min(vec), max(vec), by=step)  
  index <- match(grid, vec)  
  
  if(any(is.na(index)))  
    index <- sapply(grid, function(a,b) { d <- abs(a-b); sampleone(whi  
  
  index  
}
```

Use parentheses to avoid ambiguity

```
if( (ndraws1==1) && (ndraws2>1) ) {  
  ...  
}  
  
leftval <- which( (map - start) <=0 )
```


Names: meaningful

- ▶ Make names descriptive but concise
- ▶ Avoid `tmp1`, `tmp2`, ...
- ▶ Only use `i`, `j`, `x`, `y` in the simplest situations
- ▶ If a function is named `fv`, what might it do?
- ▶ If an object is called `nms`, what could it be?
- ▶ Functions as verbs; objects as nouns

Names: consistent

- ▶ `markers` VS `mnames`
- ▶ `camelCase` VS. `pothole_case`
- ▶ `nind` VS `n.var`
- ▶ If a function/object has one of these, there shouldn't be a function/object with the other.

Names: avoid confusion

- ▶ Don't use both `total` and `totals`
- ▶ Don't use both `n.cluster` and `n.clusters`
- ▶ Don't use both `result` and `results`
- ▶ Don't use both `Mat` and `mat`
- ▶ Don't use both `g` and `gg`

Comments

- ▶ Comment the tricky bits and the major sections
- ▶ Don't belabor the obvious
- ▶ Don't comment bad code; rewrite it
- ▶ Document the input/output and purpose, not the mechanics
- ▶ Don't contradict the code
 - this happens if you revise the code but don't revise the related comments
- ▶ Comment code as you are writing it (or before)
- ▶ Plan to spend 1/4 of your time commenting

Error/warning messages

- ▶ Explain what's wrong (and where)
 - `error("nrow(X) != nrow(Y)")`
- ▶ Suggest corrective action
 - `"You need to first run calc.genoprob()."`
- ▶ Give details
 - `"nrow(X) (" , nrX, ") != nrow(Y) (" , nrY, ")"`
- ▶ Don't give error/warning messages that users won't understand.
 - `X'X is singular.`
- ▶ Don't let users do something stupid without warning
- ▶ Include error checking even in personal code.

Check data integrity

- ▶ Check that the input is as expected, or give warnings/errors.
- ▶ Write these in the first pass (though they're dull).
 - You may not remember your assumptions later
- ▶ These are useful for **documenting** the assumptions.

Program organization

- ▶ Break code into separate files (say 300 lines?)
- ▶ Each file includes related functions
- ▶ Files should be named meaningfully
- ▶ Include a **brief** comment at the top.

Create an R package!

- ▶ Make a personal package with bits of your own code
- ▶ Mine is R/broman, github.com/kbroman/broman

```
# qqline corresponding to qqplot
qqline2 <- function(x, y, probs = c(0.25, 0.75), qtype = 7, ...)
{
  stopifnot(length(probs) == 2)
  x <- quantile(x, probs, names=FALSE, type=qtype, na.rm = TRUE)
  y <- quantile(y, probs, names=FALSE, type=qtype, na.rm = TRUE)
  slope <- diff(y)/diff(x)
  int <- y[1L] - slope*x[1L]
  abline(int, slope, ...)
  invisible(c(intercept=int, slope=slope))
}
```


Complex data objects

- ▶ Keep disparate data together in a more complex structure.
 - lists in R
 - I also like to hide things in object `attributes`
- ▶ It's easier to pass such objects between functions
- ▶ Consider object-oriented programming

Avoiding bugs

- ▶ Learn to type well.
- ▶ Think before you type.
- ▶ Consider commenting before coding.
- ▶ Code defensively
 - Handle cases that "can't happen"
- ▶ Code simply and clearly
- ▶ Use modularity to advantage
- ▶ Think through all special cases
- ▶ Don't be in too much of a hurry

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Summary

- ▶ Get the correct answers.
- ▶ Find a clear style and stick to it.
- ▶ Plan for the future.
- ▶ Be organized.
- ▶ Don't be too hurried.
- ▶ Learn from others.