Tidy evaluation:

Programming with ggplot2 and dplyr

July 2018

Charlotte Wickham
@cvwickham
cwickham@gmail.com
cwick.co.nz

Adapted from *Tidy Tools* by Hadley Wickham

Motivation

Remove the duplication in this code

```
library(dplyr)

mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Typo: handout uses df, x1, y1 etc. instead of real variables in mtcars.

Your turn

Identify the parts that change.

Give them names.

Make a function.

Does it work?

Remove the duplication in this code

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

First identify the parts that change

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Then give them names

df

group_var

summary_var

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Now make a function

```
grouped_mean <- function(df, group_var, summary_var) {
  df %>%
     group_by(group_var) %>%
     summarise(mean = mean(summary_var))
}
```

It doesn't work 😭

```
grouped_mean <- function(df, group_var, summary_var) {
  df %>%
     group_by(group_var) %>%
     summarise(mean = mean(summary_var))
}

grouped_mean(mtcars, cyl, mpg)
#> Error: Column `group_var` is unknown
```

Vocabulary

We need some new vocabulary

Evaluated using usual R rules

```
(x - min(x)) / (max(x) - min(x))
```

```
mtcars %>%
  group_by(cyl) %>%
  summarise(mean = mean(mpg))
```

Automatically **quoted** and evaluated in a “non-standard” way

You're already familiar with this idea

```
df <- data.frame(
  y = 1,
  var = 2
)

df$y



var <- "y"
df$var
```

Predict the output!

$ automatically quotes the variable name

```
df <- data.frame(
  y = 1,
  var = 2
)

df$y
#> [1] 1

var <- "y"
df$var
#> [1] 2
```

If you want refer indirectly, must use [[instead

```
df <- data.frame(
  y = 1,
  var = 2
)

var <- "y"
df[[var]]
#> [1] 1
```

	Quoted	Evaluated
Direct	`df$y`	???
Indirect	???	`var <- "y"` `df[[var]]`

	Quoted	Evaluated
Direct	`df$y`	`df[["y"]]`
Indirect	`???`	`var <- "y"` `df[[var]]`

	Quoted	Evaluated
Direct	`df$y`	`df[["y"]]`
Indirect	😢	`var <- "y"` `df[[var]]`

Identify which arguments are auto-quoted

```
library(MASS)

mtcars2 <- subset(mtcars, cyl == 4)

with(mtcars2, sum(vs))
sum(mtcars2$am)

rm(mtcars2)
```

Can’t tell? Try running the argument alone

```
library(MASS)
#> Works

MASS
#> Error: object 'MASS' not found

# -> The 1st argument of library() is quoted
```

Can't tell? Try running the argument alone

```
subset(mtcars, cyl == 4)
#> Works

cyl == 4
#> Error: object 'cyl' not found

# -> The 2nd argument of subset() is quoted
```

You can now identify the quoted arguments

```
library(MASS)

mtcars2 <- subset(mtcars, cyl == 4)

with(mtcars2, sum(vs))
sum(mtcars2$am)

rm(mtcars2)
```

Evaluated using usual R rules

Automatically **quoted** and evaluated in a “non-standard” way

Base R has 3 primary ways to “**unquote**”

Quoted/Direct	Evaluated/Indirect	
`df$y`	`x <- "y"` `df[[x]]`	Use a different function
`rm(mtcars)`	`x <- "mtcars"` `rm(list = x)`	Use a different argument
`library(MASS)`	`x <- "MASS"` `library(x, character.only = TRUE)`	Specify an additional argument

Identify which arguments are auto-quoted

```
library(tidyverse)

mtcars %>% pull(am)

by_cyl <- mtcars %>%
  group_by(cyl) %>%
  summarise(mean = mean(mpg))

ggplot(by_cyl, aes(cyl, mean)) +
  geom_point()
```

```
# OR
library(dplyr)
library(ggplot2)
```

Typo

Identify which arguments are auto-quoted

```
library(tidyverse)

mtcars %>% pull(am)

by_cyl <- mtcars %>%
  group_by(cyl) %>%
  summarise(mean = mean(mpg))

ggplot(by_cyl, aes(cyl, mean)) +
  geom_point()
```

	Quoted	Evaluated	Tidy
Direct	`df$y`	`df[["y"]]`	`pull(df, y)`
Indirect	😢	`var <- "y"` `df[[var]]`	???

	Quoted	Evaluated	Tidy
Direct	`df$y`	`df[["y"]]`	`pull(df, y)`
Indirect	😢	`var <- "y"` `df[[var]]`	`var <- quo(y)` `pull(df, !!var)`

Everywhere in the tidyverse uses !! to unquote

Pronounced bang-bang

```
x_var <- quo(cyl)
y_var <- quo(mpg)

by_cyl <- mtcars %>%
  group_by(!!x_var) %>%
  summarise(mean = mean(!!y_var))

ggplot(by_cyl, aes(!!x_var, mean)) +
  geom_point()
```

Rewrite to specify the column indirectly

```
var <- quo(cyl)

# Re-write to specify column indirectly
mtcars %>%
  summarise(
    avg = mean(cyl),
    sd = sd(cyl),
    n = sum(!is.na(cyl))
  )
```

Rewrite to specify the column indirectly

```
var <- quo(cyl)

# Re-write to specify column indirectly
mtcars %>%
  summarise(
    avg = mean(!!var),
    sd = sd(!!var),
    n = sum(!is.na(!!var))
  )

#       avg       sd  n
# 1 6.1875 1.785922 32
```

Rewrite to specify the column indirectly

```
var <- quo(mpg)
```

Change in **one** place

```
# Re-write to specify column indirectly
mtcars %>%
  summarise(
    avg = mean(!!var),
    sd = sd(!!var),
    n = sum(!is.na(!!var))
  )

#       avg       sd  n
# 1 20.09062 6.026948 32
```

A recipe for:

Wrapping quoting functions

(More theory later...)

New: Identify quoted vs. evaluated arguments

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Typo: handout uses df, x1, y1 etc. instead of real variables in mtcars.

New: Identify quoted vs. evaluated arguments

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Then identify the parts that could change

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

These become the function arguments

df

group_var

summary_var

```
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(mpg))
mtcars %>% group_by(cyl)  %>% summarise(mean = mean(wt))
mtcars %>% group_by(gear) %>% summarise(mean = mean(mpg))
mtcars %>% group_by(gear) %>% summarise(mean = mean(wt))
```

Next write the function template & identify quoted arguments

```
grouped_mean <- function(df, group_var, summary_var) {



    df %>%
      group_by(group_var) %>%
      summarise(mean = mean(summary_var))
}
```

New: Wrap every quoted argument in enquo()

```
grouped_mean <- function(df, group_var, summary_var) {
    group_var <- enquo(group_var)
    summary_var <- enquo(summary_var)

    df %>%
      group_by(group_var) %>%
      summarise(mean = mean(summary_var))
}
```

New: And then unquote with !!

```
grouped_mean <- function(df, group_var, summary_var) {
    group_var <- enquo(group_var)
    summary_var <- enquo(summary_var)

    df %>%
      group_by(!!group_var) %>%
      summarise(mean = mean(!!summary_var))
}
```

What happens when you call grouped_mean()?

```
grouped_mean(mtcars, cyl, mpg)

grouped_mean <- function(df, group_var, summary_var) {
   group_var <- enquo(group_var)
   summary_var <- enquo(summary_var)

   df %>%
     group_by(!!group_var) %>%
     summarise(mean = mean(!!summary_var))
}
```

What happens when you call grouped_mean()?

```
grouped_mean(mtcars, cyl, mpg)

grouped_mean <- function(df, group_var, summary_var) {
   group_var <- quo(cyl)
   summary_var <- quo(mpg)

   df %>%
     group_by(!!group_var) %>%
     summarise(mean = mean(!!summary_var))
}
```

What happens when you call grouped_mean()?

```
grouped_mean(mtcars, cyl, mpg)

grouped_mean <- function(df, group_var, summary_var) {
   group_var <- quo(cyl)
   summary_var <- quo(mpg)

   df %>%
     group_by(cyl) %>%
     summarise(mean = mean(mpg))
}
```

Reduce the duplication here

```
mtcars %>% summarise(avg = mean(cyl),  sd = sd(cyl),  n = sum(!is.na(cyl)))
mtcars %>% summarise(avg = mean(mpg),  sd = sd(mpg),  n = sum(!is.na(mpg)))
mtcars %>% summarise(avg = mean(disp), sd = sd(disp), n = sum(!is.na(disp)))
```

Reduce the duplication here

```
mtcars %>% summarise(avg = mean(cyl),  sd = sd(cyl),  n = sum(!is.na(cyl)))
mtcars %>% summarise(avg = mean(mpg),  sd = sd(mpg),  n = sum(!is.na(mpg)))
mtcars %>% summarise(avg = mean(disp), sd = sd(disp), n = sum(!is.na(disp)))
```

New: Identify quoted vs. evaluated arguments

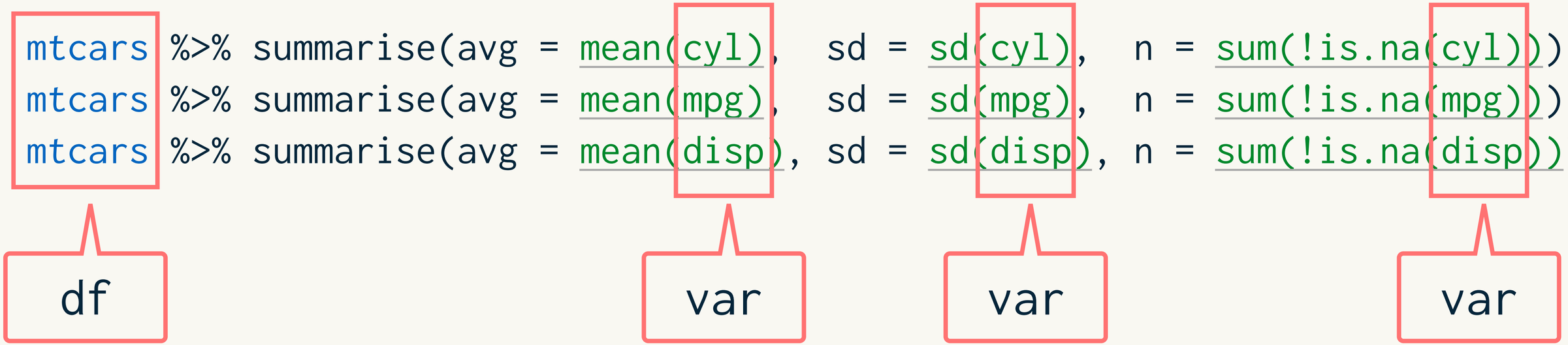
```
mtcars %>% summarise(avg = mean(cyl),  sd = sd(cyl),  n = sum(!is.na(cyl)))
mtcars %>% summarise(avg = mean(mpg),  sd = sd(mpg),  n = sum(!is.na(mpg)))
mtcars %>% summarise(avg = mean(disp), sd = sd(disp), n = sum(!is.na(disp)))
```

Then identify the parts that could change

```
mtcars %>% summarise(avg = mean(cyl),  sd = sd(cyl),  n = sum(!is.na(cyl)))
mtcars %>% summarise(avg = mean(mpg),  sd = sd(mpg),  n = sum(!is.na(mpg)))
mtcars %>% summarise(avg = mean(disp), sd = sd(disp), n = sum(!is.na(disp)))
```

These become the function arguments

```
mtcars %>% summarise(avg = mean(cyl),  sd = sd(cyl),  n = sum(!is.na(cyl)))
mtcars %>% summarise(avg = mean(mpg),  sd = sd(mpg),  n = sum(!is.na(mpg)))
mtcars %>% summarise(avg = mean(disp), sd = sd(disp), n = sum(!is.na(disp)))
```



Next write the function template & identify quoted arguments

```
summarise_column <- function(df, var){


  df %>%
    summarise(avg = mean(var),
              sd = sd(var),
              n = sum(!is.na(var)))
}
```

New: Wrap every quoted argument in enquo()

```
summarise_column <- function(df, var){

  var <- enquo(var)

  df %>%
    summarise(avg = mean(var),
              sd = sd(var),
              n = sum(!is.na(var)))
}
```

New: And then unquote with !!

```
summarise_column <- function(df, var){

  var <- enquo(var)

  df %>%
    summarise(avg = mean(!!var),
              sd = sd(!!var),
              n = sum(!is.na(!!var)))
}
```

Try it out!

```
summarise_column <- function(df, var){

  var <- enquo(var)

  df %>%
    summarise(avg = mean(!!var),
              sd = sd(!!var),
              n = sum(!is.na(!!var)))
}

summarise_column(mtcars, cyl)
#       avg        sd  n
# 1 6.1875 1.785922 32
```

Plays nicely with other tools

```
# Fits in a dplyr pipeline
mtcars %>%
  group_by(cyl) %>%
  summarise_column(mpg)

# Use purrr to iterate
my_cols <- list(quo(cyl), quo(mpg), quo(disp))
map(my_cols, summarise_column, df = mtcars)
```

Plays nicely with other tools

```
# Fits in a dplyr pipeline
mtcars %>%
  group_by(cyl) %>%
  summarise_column(mpg)

# Use purrr to iterate
my_cols <- quos(cyl, mpg, disp)
map_df(my_cols, summarise_column, df = mtcars)
```

Plural version for a list

Is it worth it?

It saves a lot of typing

```
filter(diamonds, x > 0 & y > 0 & z > 0)

# vs
diamonds[
  diamonds$x > 0 &
  diamonds$y > 0 &
  diamonds$z > 0,
]
```

It saves a lot of typing

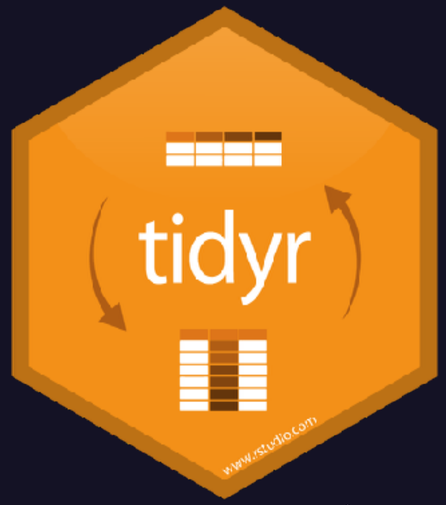
```
filter(diamonds, x > 0 & y > 0 & z > 0)

# vs
diamonds[
  diamonds["x"] > 0 &
  diamonds["y"] > 0 &
  diamonds["z"] > 0,
]
```

And makes it possible to translate to other languages

```
con <- DBI::dbConnect(RSQLite::SQLite(), filename = ":memory:")
mtcars_db <- copy_to(con, mtcars)
```

```
mtcars_db %>%
  filter(cyl > 2) %>%
  select(mpg:hp) %>%
  head(10) %>%
  show_query()

#> SELECT `mpg`, `cyl`, `disp`, `hp`
#> FROM `mtcars`
#> WHERE (`cyl` > 2.0)
#> LIMIT 10
```

Tidy evaluation = principled NSE



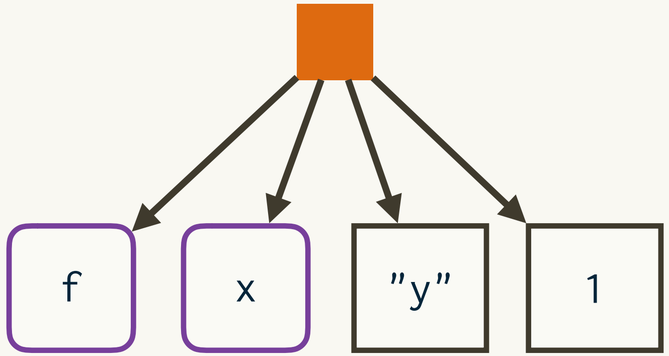
In development

Now for some ~~game~~ theory

1. R code is a tree
2. Unquoting builds trees
3. Environments map names to values

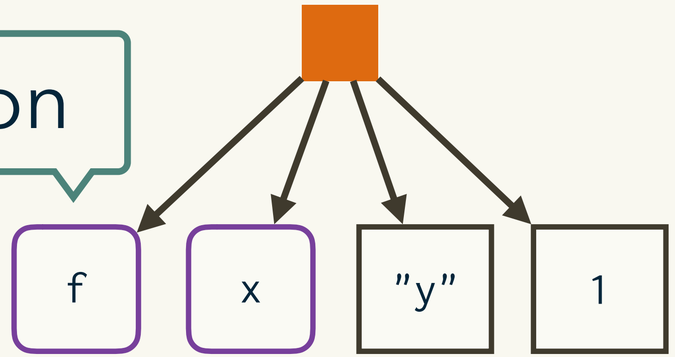
R code is a tree

```
f(x, "y", 1)
```



A function call

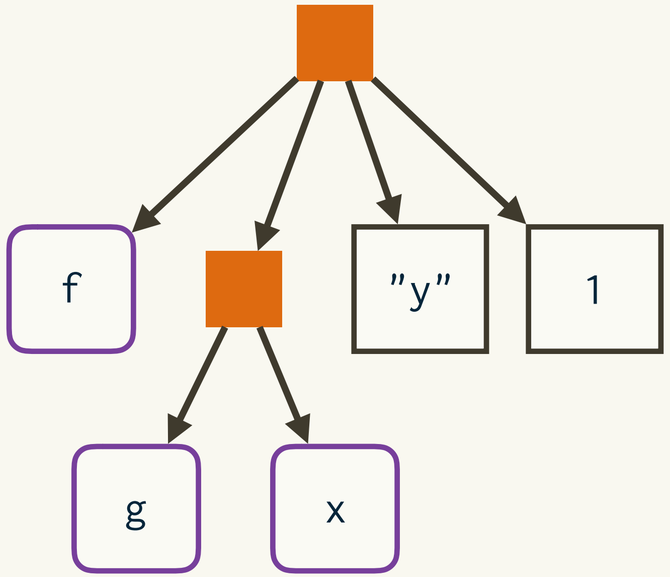
First child = function



Other children = arguments

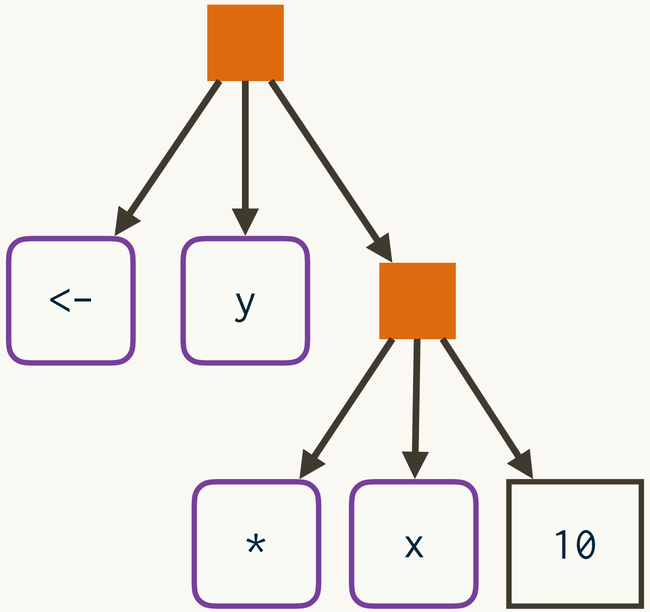
More complex calls have multiple levels

```
f(g(x), "y", 1)
```



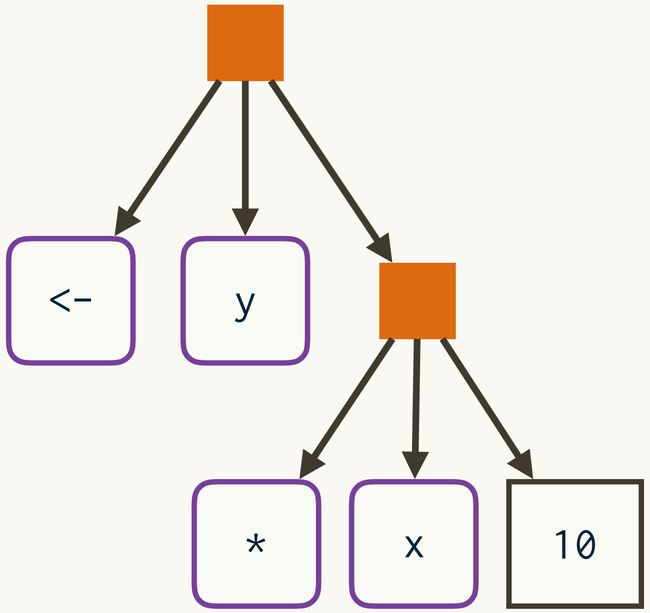
Every expression has a tree

```
y <- x * 10
```



Because every expression can be rewritten

```
`<-`(y, `*`(x, 10))
```



You can see this yourself with lobstr::ast()

```
> lobstr::ast(if(x > 5) y + 1)
■─`if`
├─■─`>`
│ ├─x
│ └─5
└─■─`+`
  ├─y
  └─1
```

Your turn

```
library(lobstr)

# Compare to my hand drawn diagrams
ast(f(x, "y", 1))
ast(y <- x * 10)

# What does this tree tell you?
ast(function(x, y) {
  if (x > y) {
    x
  } else {
    y
  }
})
```

What isn't in the AST?

```
ast(1          + 2)
ast({
  1
  # comment
  2
})
```

Unquoting builds trees

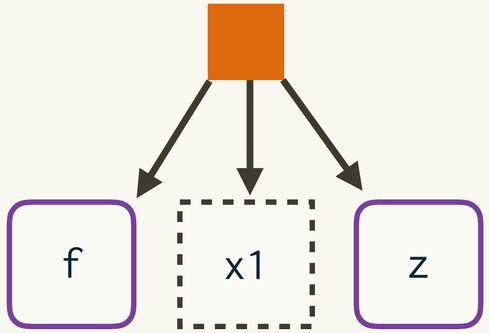
expr() captures your expression

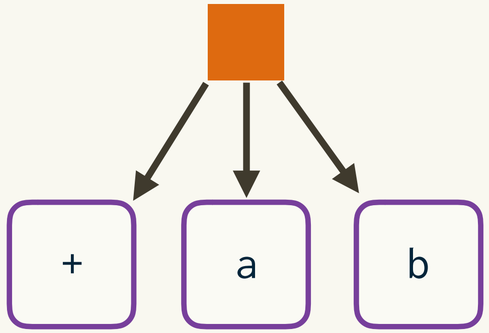
```
library(rlang)

expr(y + 1)
#> y + 1
```

Unquoting allows you to build your own trees

```
x1 <- expr(a + b)
expr(f(!!x1, z))
#> f(a + b, z)

# !! is called the unquoting operator
# And is pronounced bang-bang
```

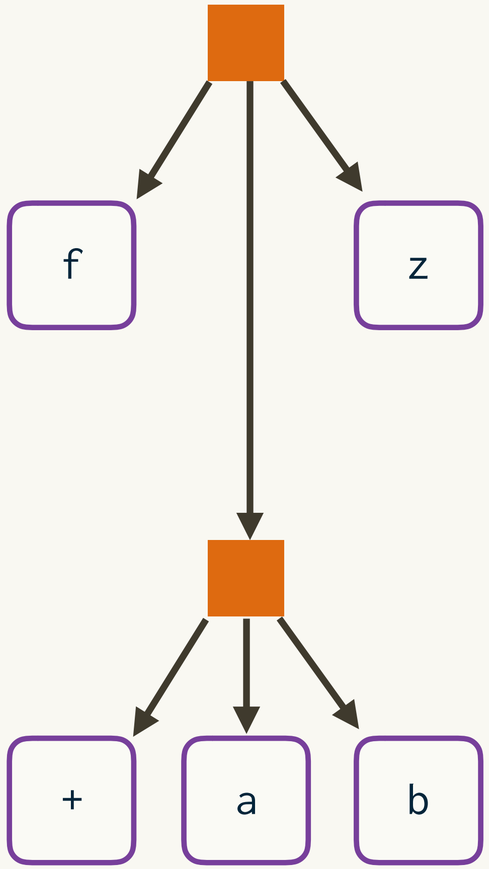
```
expr(f(!!x1, z))
```



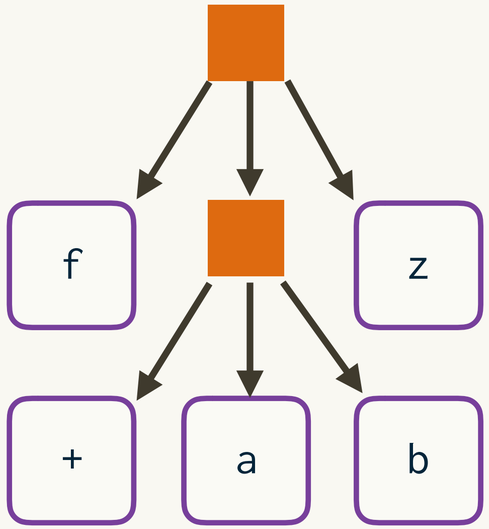



```
x1 <- expr(a + b)
```

expr(f(!!x1, z))



```
expr(f(!!x1, z))
```



Predict the contents of these expressions

```
ex1 <- expr(x + y)

ex2 <- expr(!!ex1 + z)

ex3 <- expr(1 / !!ex1)
```

Predict the contents of these expressions

```
ex1 <- expr(x + y)
# x + y
ex2 <- expr(!!ex1 + z)

ex3 <- expr(1 / !!ex1)
```

Predict the contents of these expressions

```
ex1 <- expr(x + y)
# x + y
ex2 <- expr(!!ex1 + z)
# x + y + z
ex3 <- expr(1 / !!ex1)
```

Predict the contents of these expressions

```
ex1 <- expr(x + y)
# x + y
ex2 <- expr(!!ex1 + z)
# x + y + z
ex3 <- expr(1 / !!ex1)
# 1 / (x + y)
# Not 1 / x + y
```

Recreate these expressions

```
# Using:
var <- expr(cyl)
df <- expr(mtcars)
f <- expr(foo)

# Recreate these expressions:

# mean(log(cyl))

# lm(cyl ~ 1, data = mtcars)

# foo(x = cyl)
```

Recreate these expressions

```
# Using:
var <- expr(cyl)
df <- expr(mtcars)
f <- expr(foo)

# Recreate these expressions:
expr(mean(log(!!var)))
# mean(log(cyl))
expr(lm(!!var ~ 1, data = !!df))
# lm(cyl ~ 1, data = mtcars)
expr((!!f)(x = !!var))
# foo(x = cyl)
```

enexpr() lets you capture user expressions

```
# expr() quotes your expression
f1 <- function(z) expr(z)
f1(a + b)
#> z

# enexpr() quotes user's expression
f2 <- function(z) enexpr(z)
f2(x + y)
#> x + y
```

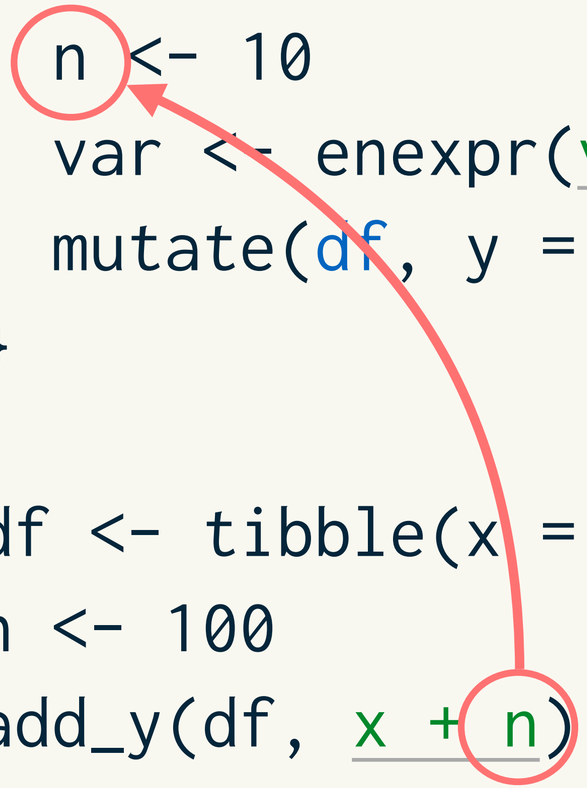
Environments map names to values

Capturing just expression isn't enough

```
add_y <- function(df, var) {
  n <- 10
  var <- enexpr(var)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00    11
```

Capturing just expression isn't enough

```
add_y <- function(df, var) {
  n <- 10
  var <- enexpr(var)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00    11
```



Capturing just expression isn't enough

```
add_y <- function(df, var) {
  n <- 10
  var <- enexpr(var)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00    11
```

Capturing just expression isn't enough

```
add_y <- function(df, var) {
  n <- 10
  var <- expr(x + n)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00    11
```

Capturing just expression isn't enough

```
add_y <- function(df, var) {
  n <- 10
  var <- expr(x + n)
  mutate(df, y = x + n)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00    11
```

quo() captures expression and environment

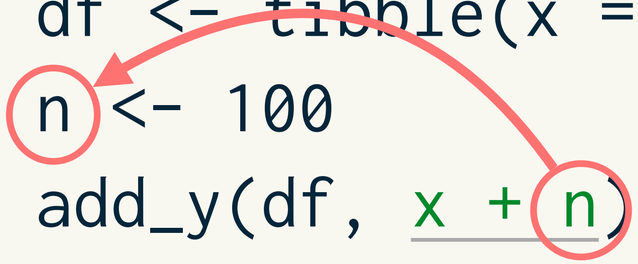
```
# quo() quotes your expression
f1 <- function(z) quo(z)
f1(a + b)
#> <quosure>
#>  expr: ^z
#>  env:  0x10d3b9308

# enquo() quotes user's expression
f2 <- function(z) enquo(z)
f2(x + y)
#> <quosure>
#>  expr: ^x + y
#>  env:  0x10d3b9309
```

	Function author	Function user
Expression	`expr(x)`	`enenxpr(x)`
Expression + environment	`quo(x)`	`enquo(x)`

Think enrich

```r
add_y <- function(df, var) {
  n <- 10
  var <- enquo(var)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>       x     y
#> 1  1.00   101
```

```r
add_y <- function(df, var) {
  n <- 10
  var <- enquo(var)
  mutate(df, y = !!var)
}

df <- tibble(x = 1)
n <- 100
add_y(df, x + n)
#>         x      y
#> 1    1.00    101
```



Key pattern is to quote and unquote

```
df <- data.frame(x = 1:5, y = 5:1, z = 0:4)
filter(df, abs(x) > 1e-3)
filter(df, abs(y) > 1e-3)
filter(df, abs(z) > 1e-3)

my_filter <- function(df, var) {
  var <- enquo(var)
  filter(df, abs(!!var) > 1e-3)
}
my_filter(df, x)
```

Typo

Quote

Unquote

Case Study

Switch to project

case_study

Your Turn

Open 03-report.R

Adapt summarise_weekly() to remove dependence on exact column names.

E.g. should be able to specify as arguments the columns for the: date, variable to be summarised, and a grouping variable.

Your Turn

```
summarise_weekly <- function(data){
  data %>%
    mutate(week = lubridate::week(date)) %>%
    group_by(type, week) %>%
    summarise(
      date = first(date),
      n = sum(!is.na(n_sales)),
      mean = mean(n_sales, na.rm = TRUE))
}
```

Your Turn

```
summarise_weekly <- function(data, date, var, group){
  date <- enquo(date)
  var <- enquo(var)
  group <- enquo(group)

  data %>%
    mutate(week = lubridate::week(!!date)) %>%
    group_by(!!group, week) %>%
    summarise(
      date = first(!!date),
      n = sum(!is.na(!!var)),
      mean = mean(!!var, na.rm = TRUE))
}
all_states_weekly <- map(all_states, summarise_weekly,
  date = date, var = n_sales, group = type)
```

How could plot_weekly() be improved?

```
plot_weekly <- function(data, title){
  data %>%
    ggplot(aes(date, mean, color = type)) +
    geom_point(size = 3) +
    geom_line(alpha = 0.5) +
    labs(title = title,
      x = "Week starting",
      y = "Average number of sales per day") +
    theme_bw() +
    scale_color_brewer(type = "qual")
}
```

How could plot_weekly() be improved?

```
plot_ts <- function(data, x, y, group, title = ""){
  x <- enquo(x)
  y <- enquo(y)
  group <- enquo(group)

  data %>%
    ggplot(aes(!!x, !!y, color =!!group)) +
    geom_point(size = 3) +
    geom_line(alpha = 0.5) +
    labs(title = title,
      x = "Week starting",
      y = "Average number of sales per day") +
    theme_bw() +
    scale_color_brewer(type = "qual")
}
all_states_plots <- map2(all_states_weekly, states_long_names, plot_ts,
 x = date, y = mean, group = type)
```

Hopefully, the end result is code that is easier to

04-report.R

```
library(tidyverse)
library(fs)

source("functions.R")

# Get file names and paths to data
files <- dir("data") %>% path_ext_remove()
file_paths <- path("data", files, ext = "csv")
states <- str_sub(files, 1, 2)
states_long_names <- c(
  "OR" = "Oregon",
  "BC" = "British Columbia",
  "WA" = "Washington")[states]

# Check data isn't too old ------------------------------------------------
ages <- check_not_outdated(file_paths)

# Import data -------------------------------------------------------------
all_states <- map(file_paths, read_csv)

# Summarise by week -------------------------------------------------------
all_states_weekly <- map(all_states, summarise_weekly,
  date = date, var = n_sales, group = type)

# Plot weekly summary -----------------------------------------------------
all_states_plots <- map2(all_states_weekly, states_long_names, plot_ts,
  x = date, y = mean, group = type)
```

1. understand,
2. maintain, and
3. extend

Once you embrace this workflow use tibbles + dplyr

```
sales
# # A tibble: 3 x 9
#   files          file_paths                states states_long_names ages
#   <fs::path>     <fs::path>                <chr>  <chr>             <time>
# 1 BC_2018-07-14 data/BC_2018-07-14.csv BC     British Columbia  6
# 2 OR_2018-07-15 data/OR_2018-07-15.csv OR     Oregon            5
# 3 WA_2018-07-18 data/WA_2018-07-18.csv WA     Washington        2
# # ... with 4 more variables: data <list>, weekly_n_sales <list>,
# #   n_sales_weekly_plot <list>, image_paths <fs::path>
```

See 05-report.R

Challenge

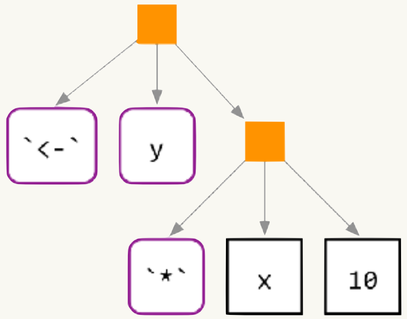
Extend the analysis to create the weekly plots for all three variables: n_sales, total_dollar_amount, n_existing_customer.

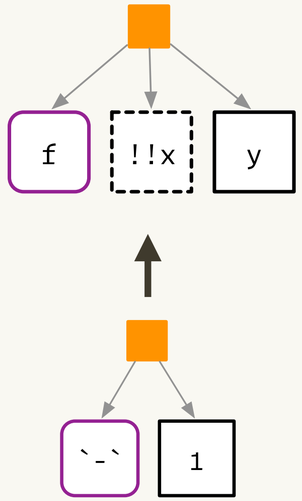
Learning more

Theory

https://youtu.be/nERXS3ssntw

Code is a tree

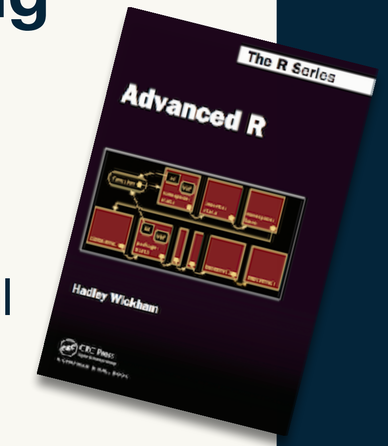




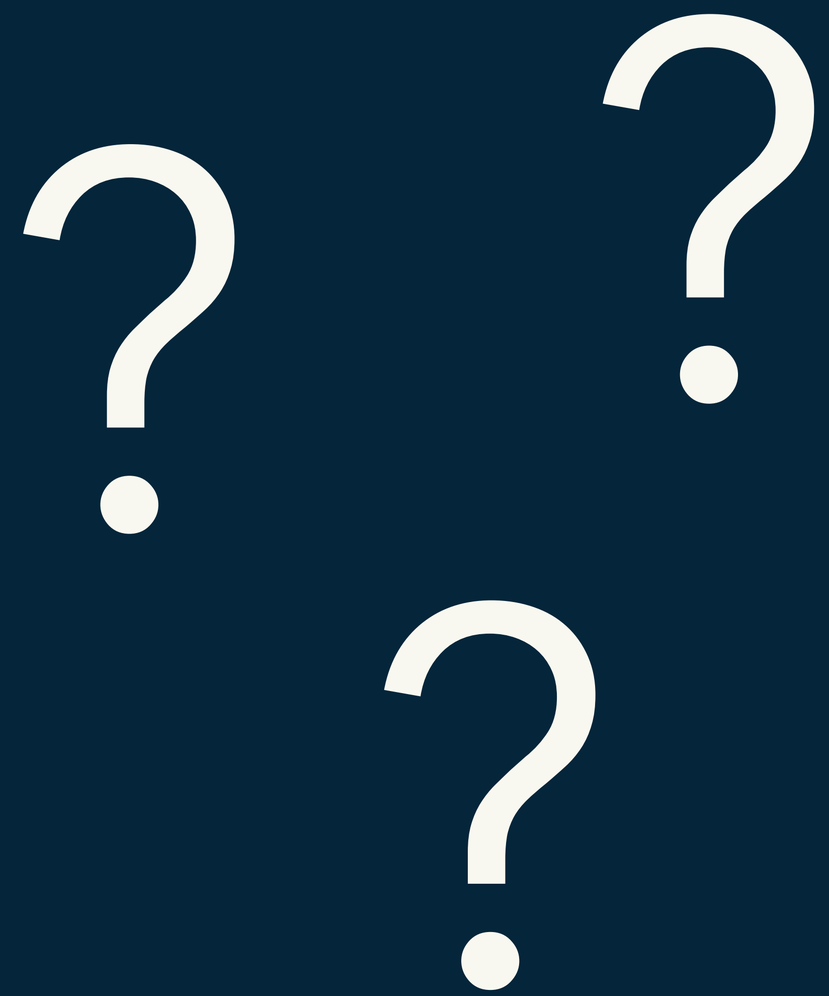
Build trees with unquoting

enquo()

https://adv-r.hadley.nz/expressions.html
https://adv-r.hadley.nz/quasiquotation.html
https://adv-r.hadley.nz/evaluation.html



Practice



Adapted from *Tidy Tools* by Hadley Wickham