Shiny's Holy Grail

Interactivity with reproducibility

Joe Cheng (@jcheng)

useR! 2019

Shiny: Interactive webapps in R

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- Allow users to **quickly explore** different parameter values, dimensions, models/algorithms
- **Faster, more visceral iteration** than modifying/rerunning a traditional R script or R Markdown report/notebook
- Great for **collaboration with domain experts** with no R expertise—no need for direct interaction with R

Demo

jcheng.shinyapps.io

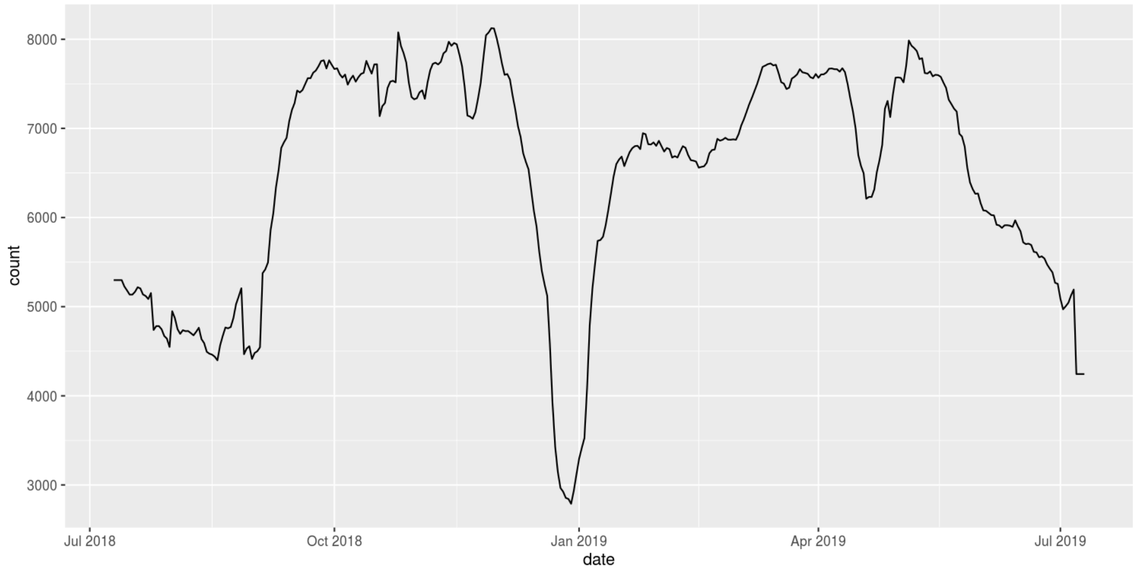
https://jcheng.shinyapps.io/shinymeta-user2019-demo1/

Package name

sp

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
      0    4054    6877    6462    8675   10677
```

Seven day rolling average



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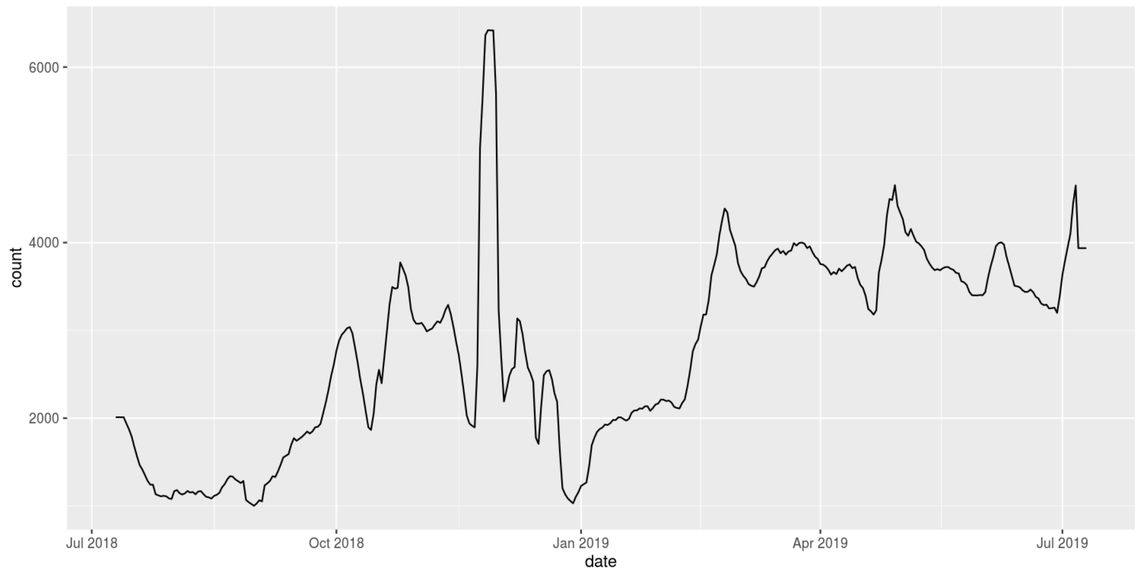
Package name

sf

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
      0    1634    2322    2787    3936   19880
```

Seven day rolling average



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  - Although bookmarking state is a thing

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- Reproducing analyses with Shiny is inconvenient: involves not just running the app, but re-enacting the same user interactions
  - Although bookmarking state is a thing
- When interactivity is not required or desired, the extra code requirements of Shiny hinder source code clarity

The goal: interactivity + reproducibility

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(You could imagine any number of other ways of bridging interactivity and reproducibility, but I'll be focusing on this specific combination for the rest of the talk.)

The goal: interactivity + reproducibility

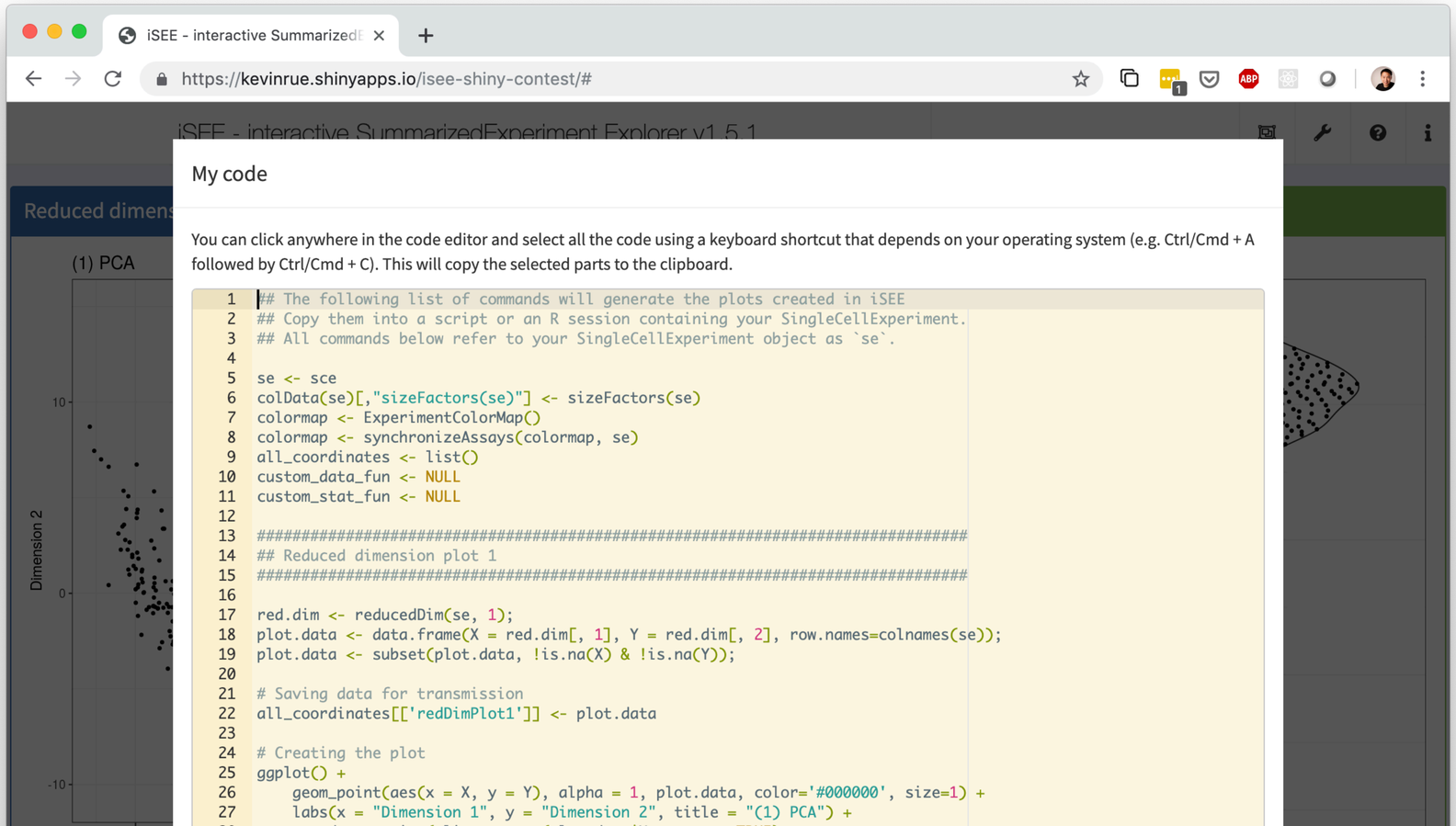
Drug research and validation
Workflows benefit greatly from interactive apps, but analysis ultimately needs to be provided in a fully reproducible form

Teaching
Interactive apps to teach statistical concepts, with corresponding code snippets to teach usage in R

Gadgets/RStudio Add-ins
Use an interactive user interface to build e.g. a ggplot2 plot, regular expression, or SQL query, then insert the corresponding code into the Source editor

Reproducible artifacts

- View an R snippet



iSEE

Reproducible artifacts

- View an R snippet
- Download standalone .Rmd or .R file

Reproducible artifacts

- View an R snippet
- Download standalone .Rmd or .R file
- Download a .zip bundle with source .Rmd/.R, plus…?
  - The outcome of running/rendering the source/script
  - Data files or supporting source code (functions.R)

Demo

jcheng.shinyapps.io

https://jcheng.shinyapps.io/shinymeta-user2019-demo2/

Package name

sp

```
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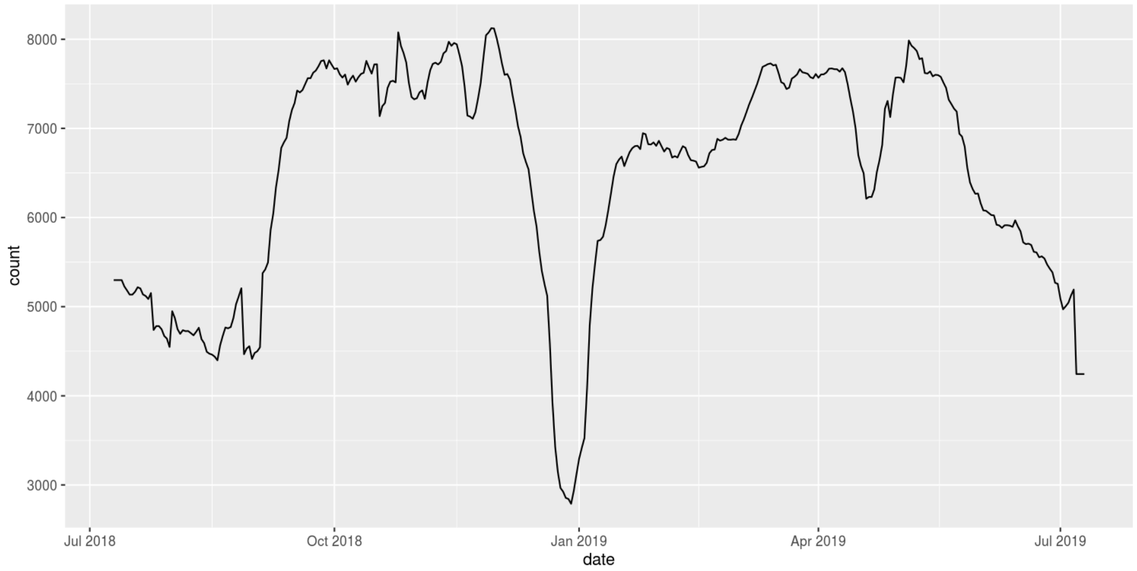
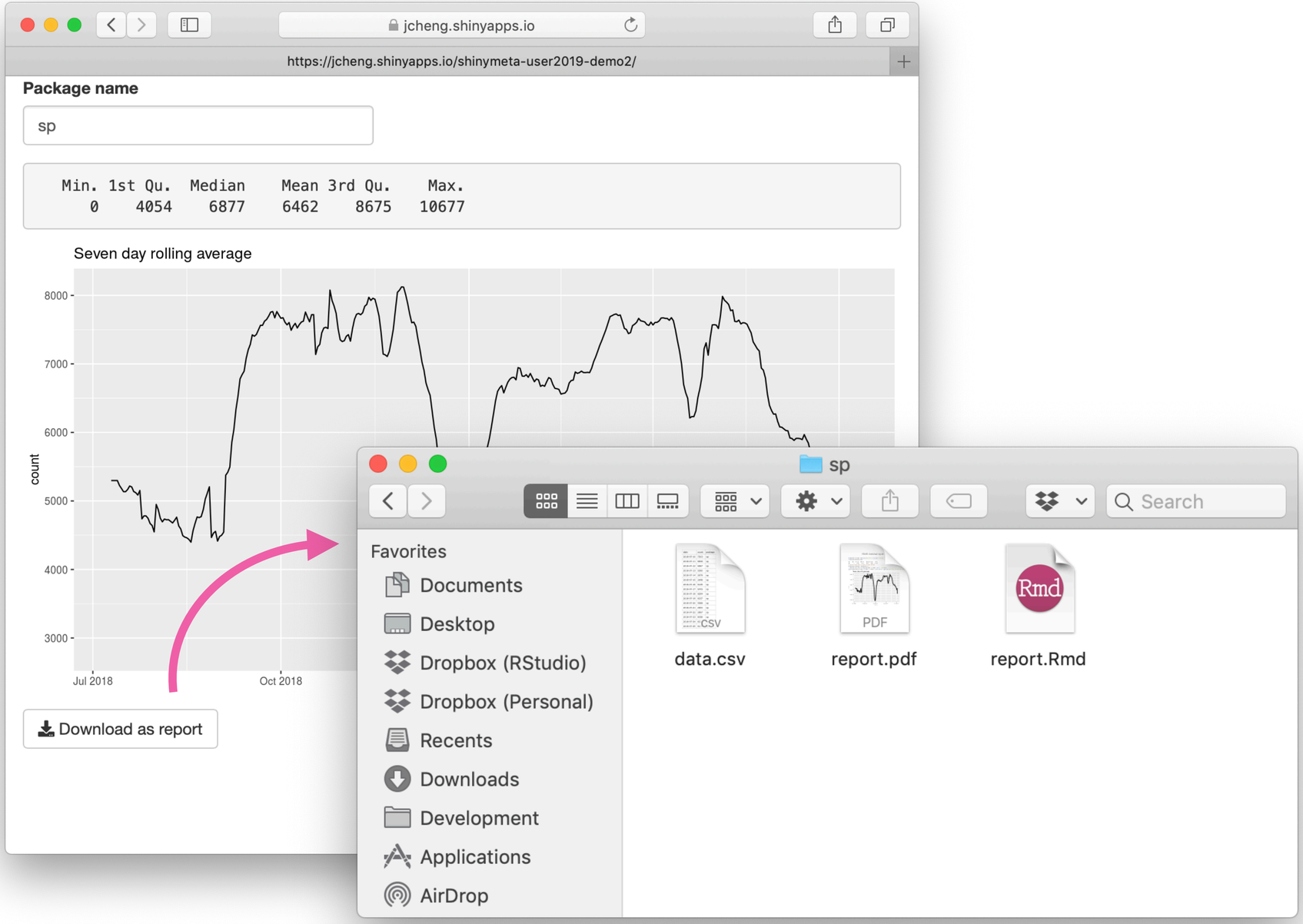
      0    4054    6877    6462    8675   10677
```

Seven day rolling average



Download as report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- **Reactive structure** is the Shiny-specific server code that makes that analysis interactive

Shiny app development equals adding reactive structure to your domain logic.

Now we want to take a Shiny app and **extract the domain logic** back out of the reactive structure.

Converting R script to Shiny

```
downloads <- cranlogs::cran_downloads("ggplot2",
  from = Sys.Date() - 365, to = Sys.Date())

downloads_rolling <- downloads %>%
  mutate(count = zoo::rollapply(count, 7, mean, fill = "extend"))

ggplot(downloads_rolling, aes(date, count)) +
  geom_line() +
  ggtitle("Seven day rolling average")
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Converting Shiny app to R script

```
downloads <- cranlogs::cran_downloads("dplyr",
  from = Sys.Date() - 365, to = Sys.Date())

downloads_rolling <- downloads %>%
  mutate(count = zoo::rollapply(count, 7, mean, fill = "extend"))

ggplot(downloads_rolling, aes(date, count)) +
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R script

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downloads <- cranlogs::cran_downloads("dplyr",
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ggplot(downloads_rolling, aes(date, count)) +
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```

Approach 1: Copy and paste

Create and maintain two separate artifacts: Shiny app and R Markdown report

- 😘 Easy to understand
- 😘 Reproducible code is high fidelity
- 😢 Two copies of code to keep in sync
- 😢 Will not work for more dynamic apps (i.e. not only changing *parameters*, but changing *instructions*)

Approach 2: Lexical analysis

E.g. scriptgloss by Doug Kelkhoff

Automatically generate scripts from app source code, using static analysis and heuristics

- 😘 Very easy to add to your app
- 😘 Few decisions to make (mostly just what outputs are interesting)
- 😢 Not all apps can be translated automatically
- 😢 Generated code is not “camera ready”—still contains code relating only to Shiny structure

Approach 3: Programmatic

Use metaprogramming techniques to write code that serves dual purposes (execute interactively, and export static code)

- 😘 Generated code is almost “camera ready”
- 😘 Flexible enough to handle highly dynamic Shiny apps
- 😢 Higher learning curve
- 😢 Significant effort to adapt existing apps

Introducing shinymeta

by Joe Cheng and Carson Sievert

shinymeta

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This package is experimental

- Not tested by QA (yet)
- Function API is still evolving

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“Scientists build to learn; Engineers learn to build.” —Fred Brooks

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downloads <- reactive({
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What was wrong with Shiny's existing reactive objects?

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- Call `downloads()` to retrieve the current dataset

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```

- Call `downloads()` to retrieve the current dataset
- Automatically caches the result until `input$package` changes
- Works well for regular Shiny apps, BUT there's no easy way for us to get the code out

1. A new family of reactive objects

With shinymeta:

```
downloads <- metaReactive({
  cranlogs::cran_downloads(input$package,
    from = Sys.Date() - 365, to = Sys.Date())
})
```

- A `metaReactive` does everything a regular `reactive` does, plus, can give you its own source code at runtime

1. A new family of reactive objects

With shinymeta:

```
downloads <- metaReactive({
  cranlogs::cran_downloads(input$package,
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```

```
> withMetaMode(downloads())
cranlogs::cran_downloads(input$package, from =
Sys.Date() - 365, to = Sys.Date())
```

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With shinymeta:

All code inside a metaReactive block is considered domain logic

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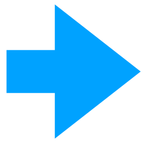
`reactive`		`metaReactive` `metaReactive2`
`observe`		`metaObserve` `metaObserve2`
`renderXXX`		`metaRender` `metaRender2`

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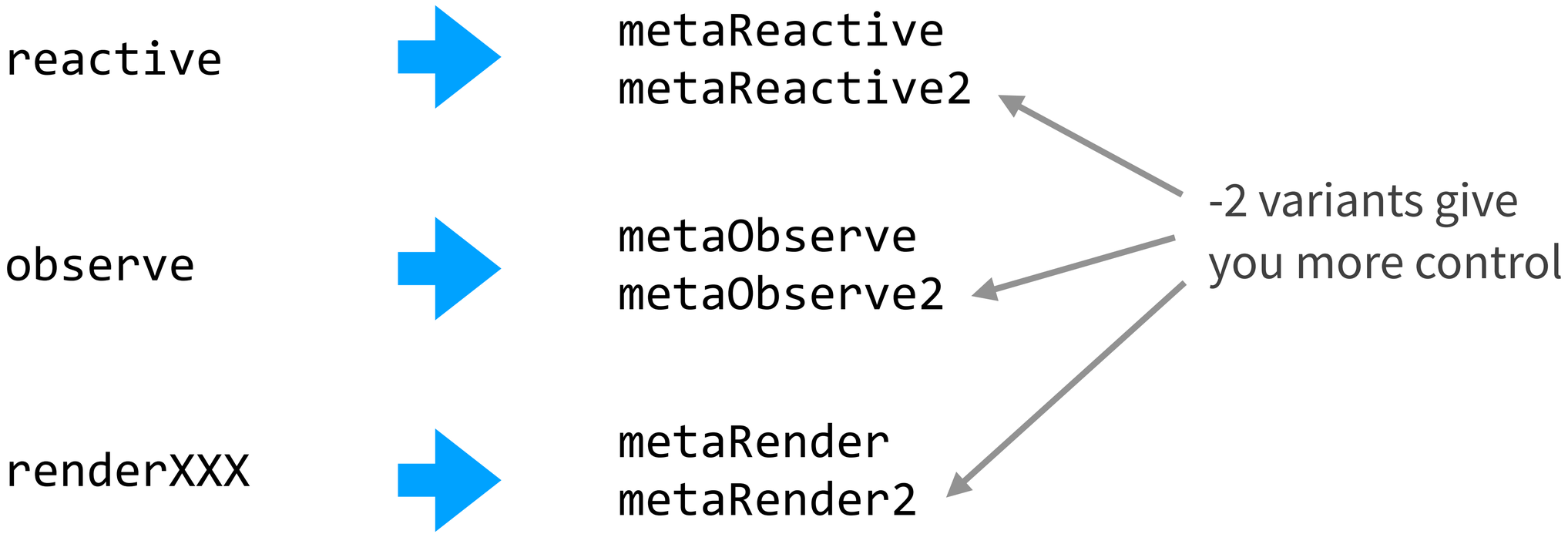

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Sometimes `metaReactive` is too coarse-grained to separate our domain logic from the Shiny stuff:

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> downloads <- metaReactive({
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Not domain logic

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Use `metaReactive2` to tell shinymeta you don't want the entire code chunk, just the part you wrap with `metaExpr()` and return it

```
> downloads <- metaReactive2({
+   req(input$package)
+   metaExpr(cranlogs::cran_downloads(input$package,
+     from = Sys.Date() - 365, to = Sys.Date()))
+ })

> withMetaMode(dataset())
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downloads_rolling <- reactive({
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output$plot <- renderPlot({
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2. De-reference reactive values using `!!`

Use `!!` to replace some code with its value.

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We need the *value of* `input$package` here, not *literally* `input$package`

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2. Within that domain logic, you **identify references to reactive values and reactive expressions** that need to be replaced with static values and static code, respectively
3. At runtime, **choose which pieces** of domain logic to export, and in what order
4. **Present the code** to the user (in a window, as a downloadable script or report, etc.)

3. Extract code from selected objects

As we've already seen, you can call meta-reactive objects within `withMetaMode()` to extract their code.

```
> downloads <- metaReactive({
+   cranlogs::cran_downloads(!!input$package,
+     from = Sys.Date() - 365, to = Sys.Date())
+ })
> withMetaMode(downloads())
cranlogs::cran_downloads("ggplot2",
  from = Sys.Date() - 365, to = Sys.Date())
```

3. Extract code from selected objects

As we've already seen, you can call meta-reactive objects within `withMetaMode()` to extract their code.

But this was just for demo purposes—in most cases you'll use a smarter, higher-level function called `expandChain()`.

`withMetaMode`

- When `!!` is applied to `input$xxx`, the value is inlined.
- When `!!` is applied to a `metaReactive` read operation, the corresponding code is inlined.

`withMetaMode`

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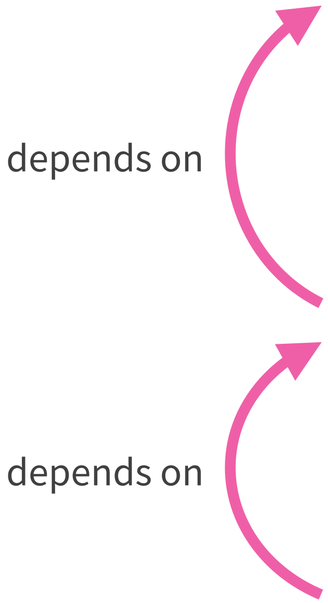
- When `!!` is applied to a `metaReactive` read operation, the corresponding code is inlined.

`expandChain`

- When `!!` is applied to `input$xxx`, the value is inlined.
- When `!!` is applied to a `metaReactive` read operation, **a new variable is introduced if one doesn't already exist**.

Example Shinymeta app




```
downloads <- metaReactive2({
  req(input$packages)
  metaExpr(cranlogs::cran_downloads(!!input$packages,
    from = Sys.Date() - 365, to = Sys.Date()))
})

downloads_rolling <- metaReactive({
  !!downloads() %>%
    mutate(count = zoo::rollapply(count, 7, mean, fill = "extend"))
})

output$plot <- metaRender(renderPlot, {
  ggplot(!!downloads_rolling(), aes(date, count)) +
    geom_line() +
    ggtitle("Seven day rolling average”)
})
```

withMetaMode(output$plot())

```
ggplot(!!downloads_rolling(), aes(date, count)) +
  geom_line() +
  ggtitle("Seven day rolling average")
```

withMetaMode(output$plot())

```
ggplot({
  # Convert daily data to 7 day rolling average
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    mutate(count = zoo::rollapply(count, 7, mean, fill =
"extend"))
}, aes(date, count)) +
  geom_line() +
  ggtitle("Seven day rolling average")
```

withMetaMode(output$plot())

```
ggplot({
  # Convert daily data to 7 day rolling average
  {
    # Retrieve a year's worth of daily download data
    cranlogs::cran_downloads("dplyr", from = Sys.Date() -
365, to = Sys.Date())
  } %>%
    mutate(count = zoo::rollapply(count, 7, mean, fill =
"extend"))
}, aes(date, count)) +
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withMetaMode(output$plot())

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  } %>%
    mutate(count = zoo::rollapply(count, 7, mean, fill =
"extend"))
}, aes(date, count)) +
  geom_line() +
  ggtitle("Seven day rolling average")
```

expandChain(output$plot())

```
ggplot(!!downloads_rolling(), aes(date, count)) +
  geom_line() + ggtitle("Seven day rolling average")
```

expandChain(output$plot())

```
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expandChain(output$plot())

```
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downloads_rolling <- downloads %>%
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ggplot(downloads_rolling, aes(date, count)) +
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ggplot(downloads_rolling, aes(date, count)) +
  geom_line() + ggtitle("Seven day rolling average")
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ggplot(downloads_rolling, aes(date, count)) +
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```

As we *expand* meta-objects, we create a *chain* of variable declarations that grows upwards

expandChain(output$plot())

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# Retrieve a year's worth of daily download data
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As we *expand* meta-objects, we create a *chain* of variable declarations that grows upwards

expandChain(output$plot())

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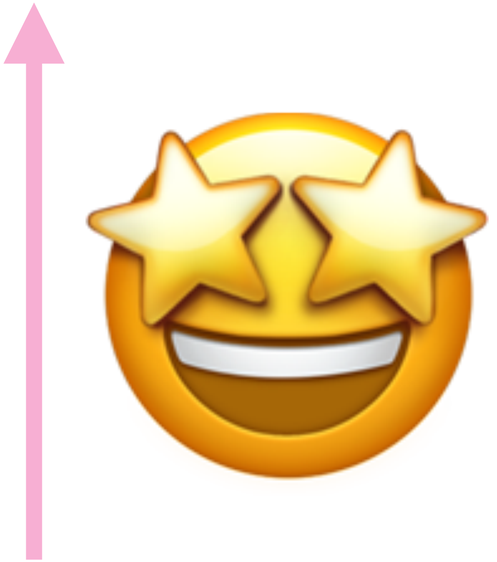
```



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Other features of `expandChain`

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- Can render multiple `meta` objects, by passing multiple arguments

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- Can render multiple `meta` objects, by passing multiple arguments
- Complex graphs of meta-reactive dependencies are automatically turned into linear code, in the correct order; each dependency object is inserted above the *first* object that needed it

```
withMetaMode(output$plot())
withMetaMode(output$summary())


ggplot({
  # Convert daily data to 7 day rolling average
  {
    # Retrieve a year's worth of daily download data
    cranlogs::cran_downloads("dplyr", from = Sys.Date() - 365, to =
Sys.Date())
  } %>%
    mutate(count = zoo::rollapply(count, 7, mean, fill = "extend"))
}, aes(date, count)) +
  geom_line() +
  ggtitle("Seven day rolling average")

summary({
  # Retrieve a year's worth of daily download data
  cranlogs::cran_downloads("dplyr", from = Sys.Date() - 365, to =
Sys.Date())
}$count)
```

```
expandChain(output$plot(), output$summary())
```

```
# Retrieve a year's worth of daily download data
downloads <- cranlogs::cran_downloads("dplyr",
  from = Sys.Date() - 365, to = Sys.Date())

# Convert daily data to 7 day rolling average
downloads_rolling <- downloads %>%
  mutate(count = zoo::rollapply(count, 7, mean, fill =
"extend"))

ggplot(downloads_rolling, aes(date, count)) +
  geom_line() + ggtitle("Seven day rolling average")

summary(downloads$count)
```

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4. Options for presenting code to users

Use `outputCodeButton()` to add a button to a *specific* output

```
plotOutput("plot")
```

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Use `outputCodeButton()` to add a button to a *specific* output

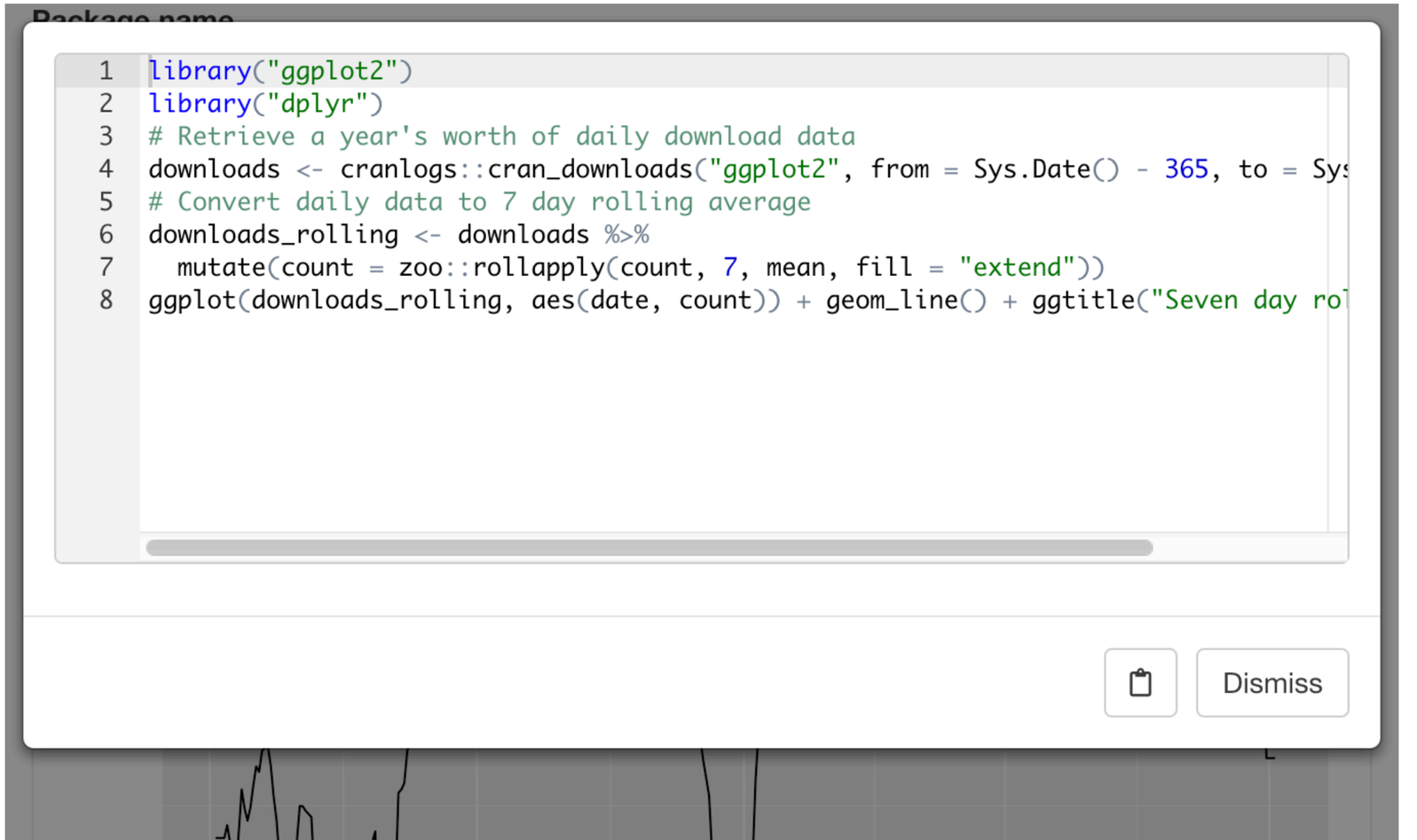
```
outputCodeButton(plotOutput("plot"))
```

4. Options for presenting code to users

Use `outputCodeButton()` to add a button to a *specific* output

4. Options for presenting code to users

Display code using `displayCodeModal()`

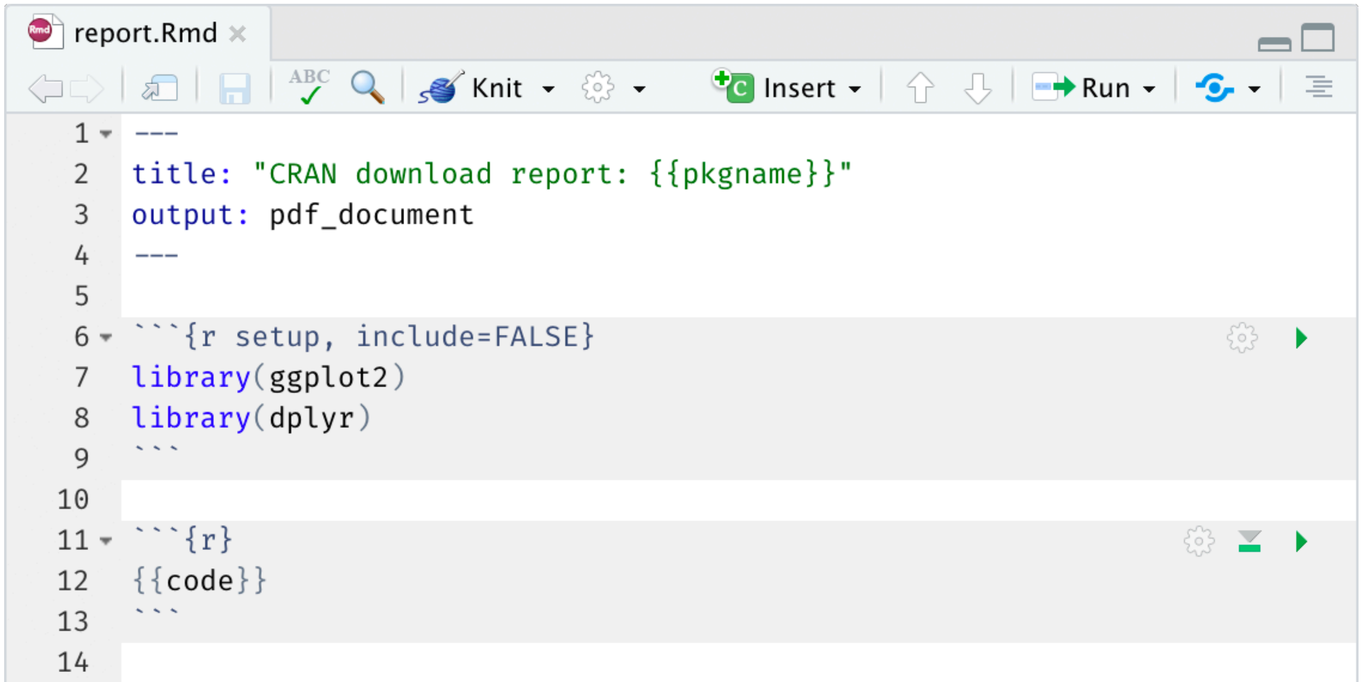


4. Options for presenting code to users

Download *.R script/*.Rmd report with `downloadButton`

Use `buildScriptBundle` or `buildRmdBundle` to dynamically generate .zip bundles

`report.Rmd`



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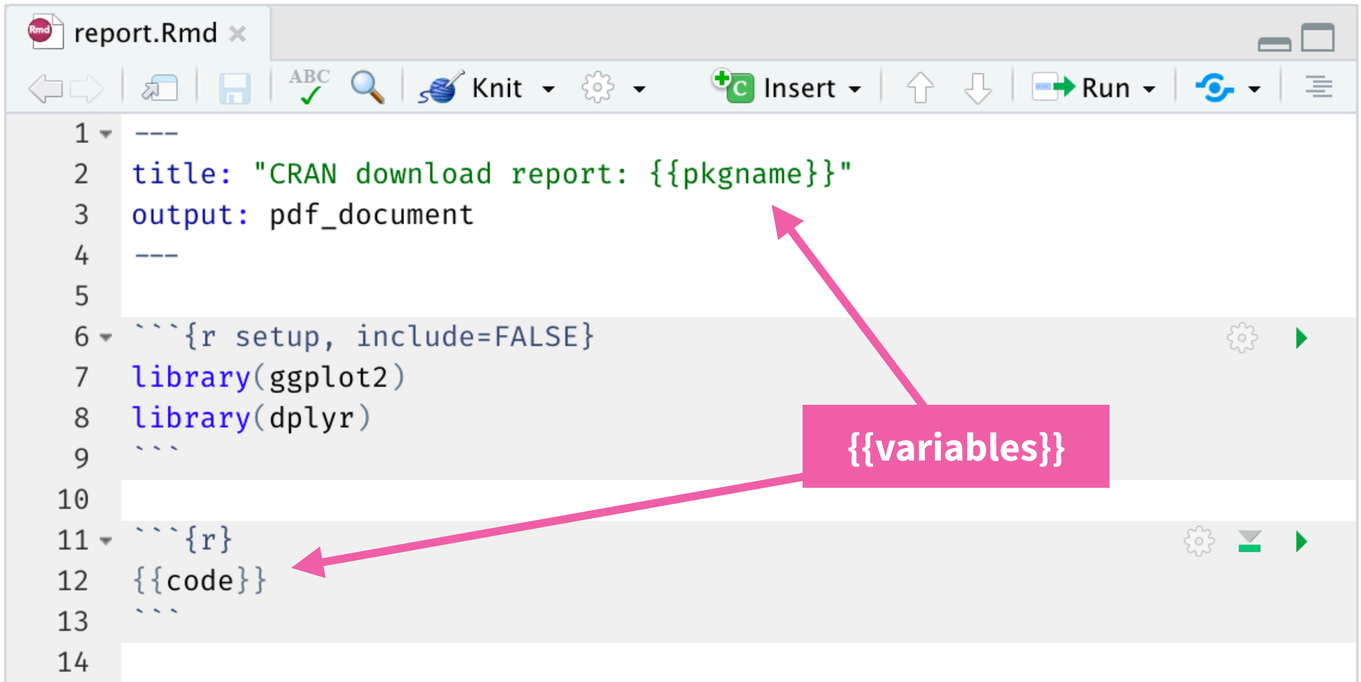

4. Options for presenting code to users

Download *.R script/*.Rmd report with `downloadButton`

Use `buildScriptBundle` or `buildRmdBundle` to dynamically generate .zip bundles

```
buildRmdBundle(
  report_template = "report.Rmd",
  include_files = list("data.csv" = downloads_data),
  vars = list(pkgname = input$package, code = code),
  output_zip_path = out
)
```

Using shinymeta (recap)

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Limitations and future directions

- Make `expandChain` extract `input`/reactive values as variables
- Formatting of generated code can improve
  - In particular, insignificant whitespace within source code is not preserved
- Compatibility with Shiny async (but should work great with both bookmarking and modules already)
- So far we've only looked at reproducing *snapshots* of app state, not necessarily "lab notebook"-style why/how/what over multiple iterations

Credits

- Special thanks to Adrian Waddell at Roche/Genentech, whose (in-house) teal framework provided direct inspiration for shinymeta
- Thanks to Doug Kelkhoff at Roche/Genentech, whose scriptgloss package provided a valuable counterpoint
- Motivated by functionality built independently by many Shiny users over the years, including Vincent Nijs (radiant); Eric Hare and Andee Kaplan (intRo); Xiao Ni (Novartis); Eric Nantz (Eli Lilly); Kevin Rue, Charlotte Soneson, Federico Marini, and Aaron Lun (iSEE); Tyler Morgan Wall (skpr)

Thank you!

Package docs:
https://rstudio.github.io/shinymeta/

Slides and examples from this talk:
https://github.com/jcheng5/shinymeta-user2019-talk

Appendix: Metaprogramming

What is metaprogramming?

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Writing code that generates/manipulates code

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Functions: `quote()`, `as.symbol()`, `call()`, `substitute()`

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Functions in the rlang package: `expr()`, `enexpr()`, `!!`

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Writing code that generates/manipulates code

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Objects: symbols, calls, expressions

Functions: `quote()`, `as.symbol()`, `call()`, `substitute()`

Functions in the rlang package: `expr()`, `enexpr()`, `!!`

(We won't attempt to cover all this today…)

Creating code objects using quote

```
dplyr::filter(diamonds, carat >= 3)
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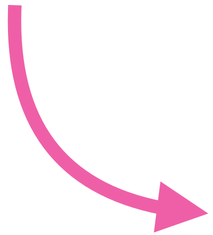

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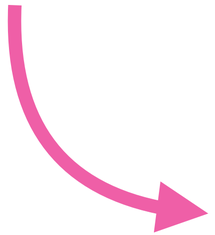

```
# A tibble: 32 x 10
   carat cut     color clarity depth table price     x     y     z
   <dbl> <ord>   <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
 1  3.01 Premium I     I1       62.7    58  8040  9.1   8.97  5.67
 2  3.11 Fair    J     I1       65.9    57  9823  9.15  9.02  5.98
 3  3.01 Premium F     I1       62.2    56  9925  9.24  9.13  5.73
 4  3.05 Premium E     I1       60.9    58 10453  9.26  9.25  5.66
 5  3.02 Fair    I     I1       65.2    56 10577  9.11  9.02  5.91
 6  3.01 Fair    H     I1       56.1    62 10761  9.54  9.38  5.31
 7  3.65 Fair    H     I1       67.1    53 11668  9.53  9.48  6.38
 8  3.24 Premium H     I1       62.1    58 12300  9.44  9.4   5.85
 9  3.22 Ideal   I     I1       62.6    55 12545  9.49  9.42  5.92
10  3.5  Ideal   H     I1       62.8    57 12587  9.65  9.59  6.03
# … with 22 more rows
```

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"dplyr::filter(diamonds, carat >= 3)"
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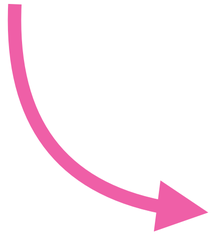

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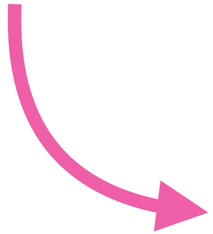

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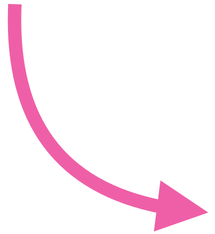

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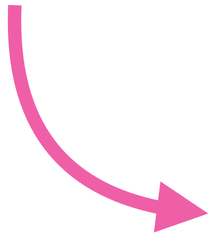
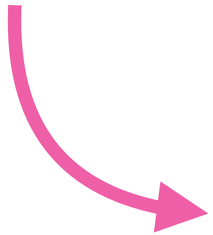


```
\- ()
  \- ()
    \- `::
    \- `dplyr
    \- `filter
  \- `diamonds
  \- ()
    \- `>
    \- `carat
    \-  3
```

(Visualized using `pryr::call_tree()`)

Creating code objects using quote

```
quote(dplyr::filter(diamonds, carat >= 3))
```



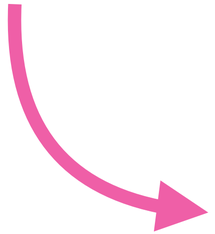
```
\- ()
  \- ()
    \- `::
    \- `dplyr
    \- `filter
  \- `diamonds
  \- ()
    \- `>
    \- `carat
    \-  3
```

(Visualized using `pryr::call_tree()`)

We can read and write nodes within this expression tree, as if it is a list of lists

Creating code objects using ~~quote~~ rlang::expr

```
rlang::expr(dplyr::filter(diamonds, carat >= 3))
```



```
\- ()
  \- ()
    \- `::
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    \- `filter
  \- `diamonds
  \- ()
    \- `>
    \- `carat
    \-  3
```

We can read and write nodes within this expression tree, as if it is a list of lists

The unquoting operator (**!!**)

The unquoting operator (`!!`)

```
> min_carat <- 3
```

The unquoting operator (`!!`)

```
> min_carat <- 3

> rlang::expr(dplyr::filter(diamonds, carat >= min_carat))
```

The unquoting operator (`!!`)

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> rlang::expr(dplyr::filter(diamonds, carat >= min_carat))
dplyr::filter(diamonds, carat >= min_carat)
```

The unquoting operator (`!!`)

```
> min_carat <- 3

> rlang::expr(dplyr::filter(diamonds, carat >= min_carat))
dplyr::filter(diamonds, carat >= min_carat)

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
```

The unquoting operator (`!!`)

```
> min_carat <- 3

> rlang::expr(dplyr::filter(diamonds, carat >= min_carat))
dplyr::filter(diamonds, carat >= min_carat)

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
dplyr::filter(diamonds, carat >= 3)
```

The unquoting operator (`!!`)

```
> min_carat <- 3

> rlang::expr(dplyr::filter(diamonds, carat >= min_carat))
dplyr::filter(diamonds, carat >= min_carat)

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
dplyr::filter(diamonds, carat >= 3)
```

Use the unquoting operator to selectively replace quoted subexpressions (like `min_carat`) with their **actual values**

The unquoting operator (**!!**)

The unquoting operator (`!!`)

```
> min_carat <- quote(quantile(diamonds$carat, probs = 0.99))
```

The unquoting operator (`!!`)

```
> min_carat <- quote(quantile(diamonds$carat, probs = 0.99))

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
```

The unquoting operator (`!!`)

```
> min_carat <- quote(quantile(diamonds$carat, probs = 0.99))

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
dplyr::filter(diamonds, carat >= quantile(diamonds$carat,probs = 0.99))
```

The unquoting operator (**!!**)

```
> min_carat <- quote(quantile(diamonds$carat, probs = 0.99))

> rlang::expr(dplyr::filter(diamonds, carat >= !!min_carat))
dplyr::filter(diamonds, carat >= quantile(diamonds$carat,probs = 0.99))
```

Use the unquoting operator to selectively replace quoted subexpressions (like `min_carat`) with **other quoted expressions**

Further reading

- That's all we'll need to know about metaprogramming for the rest of this talk, but shinymeta works best if you have a solid grasp on the following:
  - *Advanced R* (Wickham) - chapters on Non-standard evaluation and Expressions
  - The dplyr vignette *Programming with dplyr*, specifically the section on quasiquotation

Kelly Bodwin
@KellyBodwin

> stay up all night reading/writing about tidy eval
> drive to work
> this is, zero edits, what the sky looks like

Either I have finally lost my last marble, or the Universe is an #rstats user.

♡ 150 10:22 AM - Jul 2, 2019

24 people are talking about this