

# ETC4500/ETC5450

## Advanced R programming

Week 12: Interfacing with other languages



# Outline

- 1 Unit updates
- 2 R as an interface language
- 3 Interfacing other programming languages
- 4 Data analysis with databases
- 5 Creating interactive web components

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## **SETUs are now open.**

Please complete your SETU, we make improvements based on your feedback.

This is especially important for us in this unit, since it is our first year running the unit!

<https://monash.edu/ups/setu>

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# R as an interface language

R is a powerful design language, with lots of flexibility for creating good (or bad) programming interfaces.

Much of R is built up on libraries from other languages, and R's flexible interface design makes them easy to use.

## R Core

R itself is mostly written using different programming languages (mostly C and Fortran).

You can find the source code for R at

<https://svn.r-project.org/R/>, or mirrored on GitHub at  
<https://github.com/wch/r-source>

# Wrapper functions and abstractions

The use of abstraction and wrapping other software is fundamental to programming.

Wrapper functions call a second function with minimal/no change to the output. They are used to adapt existing code to work for a new design or programming language.

Wrappers often involve abstraction, a process of reducing complexity by simplifying the user-facing function's design.

# Wrapping functions with NSE

Last week we saw how non-standard evaluation (NSE) can take any syntactically valid R code and evaluate it differently.

Metaprogramming is often used to directly translate R code into other languages.

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# Interfacing other programming languages

An interface to a different programming language involves:

- Designing an R interface which can be translated into code for the other language
- Converting objects to and from each language
- Passing side-effects (like image output)

# Interfacing Python with reticulate

```
library(reticulate)
```



The reticulate package allows Python to run from within R:

- Translates R syntax to Python
- Converts R objects to Python
- Converts Python objects to R

The Python version and package environment can be set with:

```
use_python("/usr/local/bin/python")
```

# Python example from R with reticulate

```
# reticulate::py_install("numpy")
np <- import("numpy", convert = FALSE)

# do some array manipulations with NumPy
a <- np$array(c(1:4))
a
```

```
[1, 2, 3, 4]
```

```
sum <- a$cumsum()
sum
```

```
[1, 3, 6, 10]
```

```
# convert to R explicitly at the end
py_to_r(sum)
```

```
[1] 1 3 6 10
```

# Converting objects between R and Python

Full conversion table here: *Calling Python*

```
r_to_py(1)
```

```
1.0
```

```
r_to_py(1:10)
```

```
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

```
r_to_py(list(norm = rnorm(10), pois = rpois(10, 3)))
```

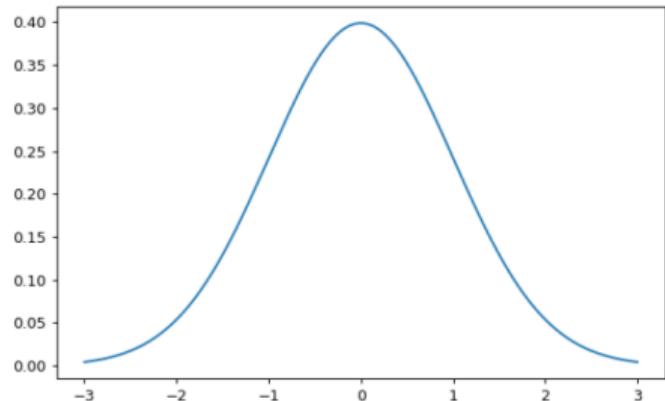
```
{'norm': [0.7202195482972471, 1.0183279054697538, 1.5434275016017769, -0.45968385077
```

```
r_to_py(mtcars)
```

```
Dict (11 items)
```

# Plots (and other side-effects)

```
plt <- import("matplotlib.pyplot")
fig <- plt$figure(figsize=c(14,8))
x <- seq(-3, 3, by = 0.01)
plt$plot(x,dnorm(x))
plt$show()
```



# Interfacing other programming languages

- Any system commands with `system()`
- C/C++: Directly in R with `.Call()` or `Rcpp` (next week!)
- Julia: `JuliaCall`
- Matlab/Octave: `R.matlab`
- Stata: `RStata`
- JavaScript: `V8`
- Java: `rJava`
- Lua: `luajr`

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# Data analysis with databases

Often data for analysis is stored and used within a database.

A database is an efficient way of securely storing and interacting with large datasets.

It is also a good technique for working with data that is too large to fit in memory.

# dbplyr

```
library(dbplyr)
```



The dbplyr package allows you to use dplyr code to manipulate tables from databases.

It achieves this using non-standard evaluation to convert dplyr and R code into suitable database code for a connected database.

# dbplyr backends

Backends are interfaces between R and database languages.

There are many database backends available for dbplyr:

- MySQL / SQLite
- Snowflake
- PostgreSQL
- Spark
- ODBC
- MS Access
- SAP HANA
- Hive
- Impala
- Oracle
- Redshift
- Teradata

# Creating a database

You can quickly create a SQLite database in memory with:

```
con <- DBI::dbConnect(RSQLite::SQLite(), ":memory:")
con
```

```
<SQLiteConnection>
Path: :memory:
Extensions: TRUE
```

Currently this database doesn't contain any tables:

```
DBI::dbListTables(con)
```

```
character(0)
```

# Using a database

We can add a dataset to the database from R with:

```
copy_to(con, mtcars)  
DBI::dbListTables(con)
```

```
[1] "mtcars"      "sqlite_stat1" "sqlite_stat4"
```

You can then retrieve the table using `tbl()`

```
tbl(con, "mtcars")
```

```
# Source:  table<`mtcars`> [?? x 11]  
# Database: sqlite 3.51.1 [:memory:]  
  mpg cyl disp hp drat wt qsec vs am gear carb  
  <dbl>  
1 21     6   160   110  3.9   2.62  16.5   0    1    4    4  
2 21     6   160   110  3.9   2.88  17.0   0    1    4    4  
3 22.8   4   108   93   3.85  2.32  18.6   1    1    4    1  
4 21.4   6   258   110  3.08  3.22  19.4   1    0    3    1  
5 18.7   8   360   175  3.15  3.44  17.0   0    0    3    2
```

# Manipulating a table

With the database table object, you can use dplyr:

```
tbl(con, "mtcars") |>  
  group_by(cyl) |>  
  summarise(mean(mpg), mean(hp))
```

```
# Source:  SQL [?? x 3]  
# Database: sqlite 3.51.1 [:memory:]  
  cyl `mean(mpg)` `mean(hp)`  
  <dbl>      <dbl>      <dbl>  
1     4          26.7        82.6  
2     6          19.7       122.  
3     8          15.1       209.
```

# Collecting the results

When your dplyr data manipulation is complete, you can then `collect()` your results as a regular R data frame for use with other packages.

```
tbl(con, "mtcars") |>  
  group_by(cyl) |>  
  summarise(mean(mpg), mean(hp)) |>  
  collect()
```

```
# A tibble: 3 x 3  
  cyl `mean(mpg)` `mean(hp)`  
  <dbl>      <dbl>      <dbl>  
1     4        26.7       82.6  
2     6        19.7      122.  
3     8        15.1      209.
```

# Disconnecting from a database

Once finished, it is good practice to disconnect from the database using DBI::dbDisconnect():

```
DBI::dbDisconnect(con)
```

See now that the database is disconnected:

```
con
```

```
<SQLiteConnection>  
DISCONNECTED
```

# Connecting to a remote database

In most cases you will be connecting to a remove database.

Here's the credentials to a PostgreSQL database containing some very important data:

- Host: arp.nectric.com.au:5432
- Username: monash
- Password: arp2024
- Database: arp

# Connecting to a remote database



Connect to the remote database and use the data.

Hint: the connection code looks like this:

```
con <- DBI::dbConnect(  
  RPostgres::Postgres(),  
  dbname = "???",  
  host = "???", port = "???",  
  user = "???", password = "???"  
)
```

# Using data on a remote database

As before, dbplyr allows you to manipulate tables using dplyr code.

```
tbl(con, "penguins") |>  
  group_by(species) |>  
  summarise(avg_mass_g = mean(body_mass_g, na.rm = TRUE))
```

All database operations are done on the remote server.

# How it works - translating expressions

dbplyr uses NSE to translate R code into SQL / database code.

You can try this out directly with `translate_sql()`:

```
translate_sql(mean(body_mass_g, na.rm = TRUE), con = con)
translate_sql(x ^ 2L, con = con)
translate_sql(substr(x, 5, 10), con = con)
```

# How it works - translating expressions

Not all R functions can be translated to database queries.

Consider `logp1()`, it gets translated directly as SQL:

```
translate_sql(logp1(x), con = con)
```

However this doesn't work, `log(body_mass_g + 1)` does.

```
tbl(con, "penguins") |>  
  mutate(logp1(body_mass_g))
```

# How it works - translating expressions

Not all database queries can be written in R.

For this you can write literal SQL commands with the `sql()` function.

```
translate_sql(sql("x!"), con = con)
translate_sql(x == sql("ANY VALUES(1, 2, 3)"), con = con)
```

# How it works - translating dplyr verbs

For any chain of dplyr commands, you can find the SQL / database query by using `show_query()` instead of `collect()`.

```
tbl(con, "penguins") |>  
  group_by(species) |>  
  summarise(avg_mass_g = mean(body_mass_g, na.rm = TRUE)) |>  
  show_query()
```

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# Creating interactive web components

In week 8 we saw how reactive programming can add interactivity to web applications using shiny.

Today we'll see how to use R and Javascript to create interactive UI elements.



## Concepts combined

The UI elements from today and the reactive server code from week 8 is all the ingredients to create shiny apps.

# Shiny extensions

There are many JS libraries which have been wrapped up into R packages, for use in Shiny or regular analysis.

<https://github.com/nanxstats/awesome-shiny-extensions>

# htmltools

```
library(htmltools)
```



The htmltools package allows you to write HTML code with R.

```
div(  
  p("Hello world!"),  
  img(src = "earth.jpg")  
)
```

```
<div>  
  <p>Hello world!</p>  
    
</div>
```

Hello world!



# htmltools

This is used to create the UI of a Shiny app.

It also includes the necessary CSS/JS dependencies for HTML reports with interactive ‘widgets’.

# htmlwidgets

The `htmlwidgets` package provides a framework for creating R bindings to JavaScript libraries. HTML Widgets can be:

- Used at the R console for data analysis just like conventional R plots.
- Embedded within R Markdown documents
- Incorporated into Shiny web applications.
- Saved as standalone web pages for ad-hoc sharing via email, file transfer, web deployment, etc.

# htmlwidgets showcase

The htmlwidgets package powers many popular R packages including:

- leaflet
- plotly
- visNetwork
- DiagrammeR

<http://www.htmlwidgets.org/>

# htmlwidgets components

All widgets include the following components:

- Web dependencies: JS and CSS assets used by the widget
- R binding: This is the function that users call to create the output
- JavaScript binding: The JavaScript code that glues everything together, passing data/options from the R binding to the underlying JavaScript library.

# htmlwidgets setup

From within a package, you can quickly get started with a htmlwidget using:

```
htmlwidgets::scaffoldWidget("mywidget")
```



Follow along!

Create a package for making interactive wordclouds.  
We'll use the wordcloud2.js library, available on GitHub  
here: <https://github.com/timdream/wordcloud2.js>

# htmlwidgets setup

The htmlwidgets components are organised in packages with this file structure:

```
R/  
| <name>.R  
  
inst/  
|-- htmlwidgets/  
|   |-- <name>.js  
|   |-- <name>.yaml  
|   |-- lib/  
|     |-- <javascript library>/
```

# Web dependencies

Dependencies are specified using the YAML configuration file located at `inst/htmlwidgets/<name>.yaml`.

```
dependencies:
  - name: <name>
    version: <version>
    src: htmlwidgets/lib/<src>
    script:
      - <JS files>
    stylesheet:
      - <CSS files>
```

# Web dependencies



Follow along!

Download the JavaScript src for wordcloud2.js and add it to the package as a htmlwidgets dependency.

The JavaScript library's sources are available in the repository's src/ folder.

<https://github.com/timdream/wordcloud2.js>

# R binding

An R function which returns a htmltools widget created with  
`htmlwidgets::createWidget()`

```
function(x, ...) {  
  # R code preparing data/settings  
  
  # Return a HTML widget  
  createWidget(  
    name, # The name of your widget in /inst  
    x, # The data/settings for the widget's JS binding  
    ...  
  )  
}
```

# R binding



Follow along!

Update the generated R binding function to:

- Accept a character vector of words.
- Accept a numeric vector of frequency/weight.
- Pass these inputs into the htmlwidget via x.

Bonus: improve the design by accepting .data as the first input, then using tidy evaluation to pass in the words and frequencies from .data.

# JavaScript binding

The JavaScript code that takes data/settings from R and uses the JS library to create the output.

```
HTMLWidgets.widget({
  name: "<name>",
  type: "output",
  factory: function(el, width, height) {
    // initialise the JavaScript object from the library here
    var obj = new <initialise object>;
    return {
      renderValue: function(x) {
        // update the initialised JavaScript object with new data/settings
      },
      resize: function(width, height) {
        // Re-render or otherwise update size when window changes
      }
    };
  }
});
```

# JavaScript binding



Follow along!

Update the generated JavaScript binding to create the word-cloud on the htmlwidgets HTML element el.

Hint: a wordcloud is created using wordcloud2.js with:

```
WordCloud(el, { list: [['foo', 12], ['bar', 6]] } );
```

Hint: The data can be transposed from two separate vectors into the above format with `HTMLWidgets.transposeArray2D([x.words, x.freqs])`

# Create a wordcloud

🔥 Your turn!

Your wordcloud function is now ready to use, try it out!

You can try it with the love words example dataset here:

```
readr::read_csv(  
  "https://arp.numbat.space/week11/lovewords.csv"  
)
```

# Use the wordclouds in a shiny app

The bindings for shiny apps are already created by `htmlwidgets::scaffoldWidget()`, and can be used in shiny like any other UI output and server renderer.

```
widgetOutput <- function(outputId, width = '100%', height = '400px'){
  htmlwidgets::shinyWidgetOutput(outputId, 'widget', width, height,
                                 package = 'package')
}

renderWidget <- function(expr, env = parent.frame(), quoted = FALSE) {
  if (!quoted) { expr <- substitute(expr) } # force quoted
  htmlwidgets::shinyRenderWidget(expr, widgetOutput, env, quoted = TRUE)
}
```