An example Quarto Markdown file

Illustrating use of R, Python, bash and Julia code chunks

1 How to generate a document from this file

From the command line, you can render the file as follows:

```
quarto render demo.qmd --to html
quarto render demo.qmd --to pdf

# Output depends on 'format' declaration at the top of the document (defaults to html):
quarto render demo.qmd
```

Alternatively, start R and run the desired line from amongst the following possibilities in R:

```
library(quarto)
quarto_render("demo.qmd") # defaults to html
quarto_render("demo.qmd", output_format = "pdf")
```

Or in RStudio (version at least 2022.07), click on the 'Render' button and choose to knit to HTML, PDF, or Word (for R Markdown).

Here is the rendered PDF version of this document.

2 Some basic Markdown formatting

Here's an *introduction* to our **critical** discovery. Here we have some code to display inline but not evaluate: `exp(7)` and we can embed the code in a static code block as follows:

```
a = 7 %% 5
b = exp(a)
```

This document will focus on embedding math and code and not on standard Markdown formatting. There are lots of sources of information on Markdown. RStudio has good information on R Markdown (including Markdown formatting).

You can directly use HTML formatting (for HTML output files) and LaTeX formatting (for PDF output files).

3 Embedding equations using LaTeX

This can be done with the following syntax. Note that you can't have a space after the initial `$` for the inline equations.

Here is an inline equation $f(x) = \int f(y, x)dy$.

Here's a displayed equation

$$f_\theta(x) = \int f_\theta(y, x)dy.$$

3.1 LaTeX macros

You can define LaTeX macros in separate files and then use them as follows.

The macros for PDF rendering should be placed in a .tex file as shown in macros.tex. The macros for HTML rendering should be placed in a .md file, formatted as shown in macros.md.

(Unfortunately, it does seem to me that you need to have two separate files with the same macro definitions if rendering to both pdf and html.)

Then make sure to include those files as seen in the header of the qmd document like this:

```
format:
  pdf:
    include-before-body:
     - file: macros.tex
  html:
    include-before-body:
     - file: macros.md
```

We can then use a macro in this equation:

$$A = X^\mathsf{T}Y$$

4 Embedding code chunks

4.1 R code

Here's an R code chunk

```
a <- c(7, 3)
mean(a)
```

```
[1] 5
```

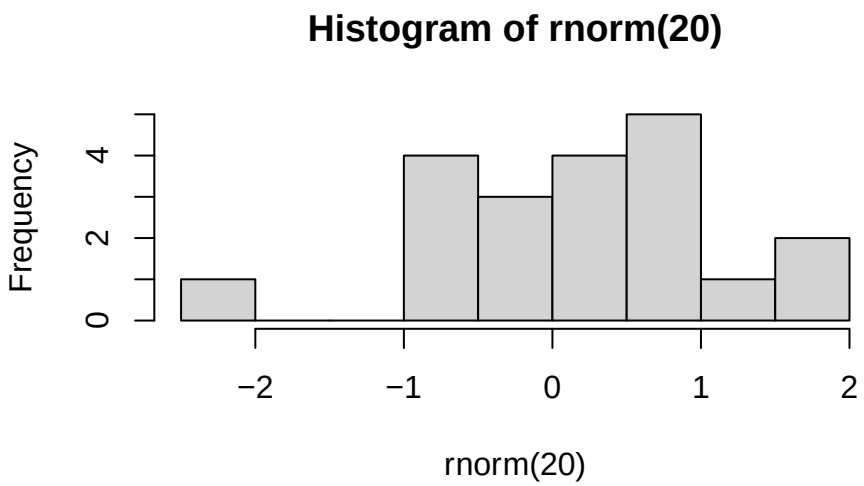
```
b <- a + 3
mean(b)
```

```
[1] 8
```

When running R code, output is printed interspersed with the code, as one would generally want. Also, later chunks have access to result from earlier chunks (i.e., state is preserved between chunks).

Let's make a plot:

```
hist(rnorm(20))
```



And here's some inline R code: What is 3 plus 5? 8.

4.2 Python code

You can embed Python code. As with R, state is preserved so later chunks can use objects from earlier chunks.

```
import numpy as np
x = np.array((3, 5, 7))
print(x.sum())
```

```
15
```

```
x.min()
```

```
3
```

```
try:
    print("state is preserved if we see the value of `x[2]` next")
    print(x[2])
except NameError:
    print('state is not preserved: x does not exist')
```

```
state is preserved if we see the value of `x[2]` next
7
```

> ⚠ Format of output from Python chunks
>
> When using the `jupyter` rendering engine, all output is printed after all the code from the chunk. When using `knitr` engine, output appears directly after the code producing the output, as shown here.
>
> ```
> print(1)
> ```
>
> ```
> 1
> ```
>
> ```
> # Whether "1" and "2" are printed after all the code or interspersed
> # depends on the engine used.
> print(2)
> ```
>
> ```
> 2
> ```

> **What output is printed from Python chunks**
>
> By default, only the output of the last line of Python code and explicit `print` calls are printed. But you can add `ipynb-shell-interactivity: all` to the yml header of the Quarto file to have all output printed.

There is no facility for inline Python code, so this: `python print(3+5)` does not print out "8".

To display code from a file of Python code, you can use functionality in the `inspect` module. This code would display the definition of `doubled()` from the `my_code` module.

```
import my_code
import inspect
print(inspect.getsource(my_code.doubled))
```

```
def doubled(x):
    return 2*x
```

This will work for functions and for class definitions.

4.3 bash code

A bash chunk:

```
ls -l assets
df -h
cd /tmp
pwd
```

```
total 99
drwxr-sr-x 2 paciorek scfstaff     3 Feb 25 14:37 css
drwxr-sr-x 6 paciorek scfstaff     6 Feb 25 14:37 fonts
drwxr-sr-x 2 paciorek scfstaff     3 Feb 25 14:37 img
drwxr-sr-x 2 paciorek scfstaff     3 Feb 25 14:37 js
-rw-r--r-- 1 paciorek scfstaff 92106 Feb 25 14:37 stat_bear.png
-rw-r--r-- 1 paciorek scfstaff    69 Feb 25 14:37 styles.css
Filesystem                      Size  Used Avail Use% Mounted on
/dev/sda2                        59G   32G   25G  57% /
tmpfs                            16G  143M   16G   1% /dev/shm
```

```
tmpfs                              3.2G  3.4M  3.2G   1% /run
tmpfs                              5.0M  4.0K  5.0M   1% /run/lock
/dev/sdb1                          111G  661M  105G   1% /tmp
/dev/sda1                          499M  6.1M  493M   2% /boot/efi
/dev/sda3                           59G   47G  9.3G  84% /var
/dev/sda5                          2.6T  1.3T  1.2T  53% /var/tmp
oz.berkeley.edu:/pool0/accounts     67T   23T   45T  34% /accounts
tmpfs                              3.2G  136K  3.2G   1% /run/user/3189
oz.berkeley.edu:/pool0/system      6.0T  4.9T  1.2T  81% /system
oz.berkeley.edu:/pool0/scratch      37T   35T  2.5T  94% /scratch
tmpfs                              3.2G   32K  3.2G   1% /run/user/1463
/tmp
```

Unfortunately, output from bash chunks occurs after all the code is printed and without any line spacing. Also, state is not preserved between chunks.

We can see that state is not preserved here, where the current working directory is NOT the directory that we changed to in the chunk above.

```
pwd  # result would be /tmp if state were preserved
```

```
/accounts/vis/paciorek/staff/tutorials/tutorial-dynamic-docs
```

Inline bash code won't work so this: `bash wc demo.Rmd` has no effect, unlike with R code.

If you are using the `jupyter` engine and want to have both bash and Python chunks in a document, or you don't want to have to install a bash Jupyter kernel, you can use ipython magic to run bash code within a Python chunk (results not shown here):

```
!echo "hello from python"
!pwd
```

One can also use `zsh` or other shell chunks, replacing the "bash" label with "zsh" or the other shell.

4.4 Embedding Julia code

You can embed Julia code. As with R and Python, state is preserved so later chunks can use objects from earlier chunks.

```
x = [3, 5, 7];
x[2]
```

```
5
```

```
try
    println("state is preserved if we see the value of `x[2]` next")
    print(x[2])
catch
    print("state is not preserved: x does not exist")
end
```

```
state is preserved if we see the value of `x[2]` next
5
```

There is no facility for inline Julia code, so this code: `julia print(3+5)` has no effect.

5 Controlling code chunk behavior

The Quarto syntax for specifying a chunk label (useful for debugging) and chunk options is as shown here, with the label defined using `#|`:

````
```{r}
#| label: put-options-in-chunk
b <- rnorm(5)
mean(b)
```
````

```
[1] 0.08123054
```

You have control over whether code in chunks is echoed (printed) into the document and evaluated using the `include`, `echo`, and `eval` tags.

Here we print out the code, but we don't evaluate it:

````
```{r}
#| label: evalChunk
#| eval: false
cat("This code is printed in the document, but the code is not evaluated.")
mean(b)
```
````

Here's the result of a chunk with `echo` set to `false` so the code itself does not show up in the rendered document.

```
This code is not printed in the document, but results of evaluating the code are printed.
```

Here's a chunk with `include` set to `false`, hence neither the code nor output from running the code show up in the rendered output.

Results of intensive calculations can be saved using the `cache: true` tag so they don't need to be rerun every time you compile the document.

````
```{r}
#| label: slow-step
#| cache: true
a <- mean(rnorm(5e7))
a
```
````

```
[1] 8.558468e-05
```

You can use variables (an R variable here) to control the chunk options. Note that the variable `myControlVar` is defined in the first chunk of this document. Here it is used to turn off evaluation of the chunk code.

````
```{r}
#| label: use-var-in-chunk-option
#| eval: !expr '!myControlVar'
print("hi")
mean(b)
```
````

You can control which executable is used to execute a given chunk of code by (particularly useful for Python and bash and for debugging), using the `engine.path` chunk option.

````
```{python}
#| eval: false
#| engine.path: /usr/bin/python2
a = 3
print a
```
````

It's not uncommon to have various Python executables installed (different versions, in Conda/Mamba environments, etc.) on your system or to be unclear about which shell is being used to execute a shell chunk. Manually setting `engine.path` can help figure things out or work around problems.

6 Reading code from an external file

It's sometimes nice to draw code in from a separate file. Before invoking a chunk, we need to read the chunks from the source file, which contains the chunks tagged with some special formatting.

This only works with the `knitr` engine.

````
```{r}
#| label: read-chunk
library(knitr)
read_chunk('demo.R')  ## contains external_chunk_1 and external_chunk_2 of R code
read_chunk('demo.py')  ## contains external_chunk_3 of Python code
```
````

Note that a good place for reading the source file via `read_chunk()` is in an initial setup chunk at the beginning of the document.

Here are two R chunks whose code is in `demo.R`.

```
a <- 7
cat("a is ", a, ".\n", sep = "")
```

```
a is 7.
```

```
a <- 9
cat("Now, a is ", a, ".\n", sep = "")
```

```
Now, a is 9.
```

And here is a Python chunk whose code is in `demo.py`.

```
a = [3,4,5]
print(len(a))
```

```
3
```

As mentioned earlier, to display function or class definitions from a file of Python code, you can use functionality in the `inspect` module. This code would display the definition of `doubled()` from the `my_code` module.

```
import my_code
import inspect
print(inspect.getsource(my_code.doubled))
```

7 Formatting of long lines of code and of output

In general, it's best to keep lines of code to at most 80 characters. This will help with code readability in the file with the code and with the output that is rendered not going into the margin.

For HTML output, you can set `code-overflow: wrap` in the yml frontmatter to enforce line-wrapping for code.

For PDF output, you can insert the following LaTeX in the yml frontmatter:

```
include-in-header:
  text: |
    \usepackage{fvextra}
    \DefineVerbatimEnvironment{Highlighting}{Verbatim}{breaklines,commandchars=\\\{\}}
```

7.1 R code

Having long lines be nicely formatted and other aspects of formatting can be a challenge. Also, results can differ depending on your output format (e.g., PDF vs. HTML). In general the code in this section will often overflow the page width in PDF but not in HTML, but even in the HTML the line breaks may be awkwardly positioned.

Here are some examples that overflow in PDF output.

```
b <- "Statistics at UC Berkeley: We are a community engaged in research and education in prob
## Statistics at UC Berkeley: We are a community engaged in research and education in probab

## This might work to give decent formatting in HTML but doesn't in PDF.
cat(b, fill = TRUE)
```

```
Statistics at UC Berkeley: We are a community engaged in research and education in probabilit
```

```
vecWithALongName = rnorm(100)
a = length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) + vecWithALon
a = length(mean(5 * vecWithALongName + vecWithALongName)) # this is a comment that goes over
a = length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) + vecWithALon
```

In contrast, long output is usually fine, even in PDF.

```
rnorm(30)
```

```
 [1] -1.04437702  0.51995461  0.15155954  0.55836893 -1.87940055 -0.99908618
 [7] -0.47083913  0.88461719 -2.47235000  1.55333948  1.41114869  1.91056609
[13] -0.62932679  1.22380063  1.12960580 -0.84659648 -0.65229492  1.83760743
[19] -1.32678114  0.50964439 -0.80747544 -0.03085863 -0.91200119  0.82473210
[25]  0.70518136 -0.84725563 -1.07806906  1.38768940  1.11856234  0.24872574
```

Adding the `tidy: true` chunk option and setting the width as shown below can help with long comment lines or lines of code, but doesn't help for some of the cases above.

```
## Long strings and long comments:

b <- "Statistics at UC Berkeley: We are a community engaged in research and education in prob
## Statistics at UC Berkeley: We are a community engaged in research and
## education in probability and statistics. In addition to developing
## fundamental theory and methodology, we are actively

## This might work to give decent formatting in HTML but doesn't in PDF:

cat(b, fill = TRUE)
```

```
Statistics at UC Berkeley: We are a community engaged in research and education in probabilit
```

```
## Now consider long lines of code:

vecWithALongName <- rnorm(100)
a <- length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) +
    vecWithALongName * vecWithALongName, na.rm = TRUE))
a <- length(mean(5 * vecWithALongName + vecWithALongName))  # this is a comment that goes ove
a <- length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) +
    vecWithALongName, na.rm = TRUE))  # this is a comment that goes over the line by a good l
```

To address the problems seen above, sometimes you can format things manually for better results. In that case, you may need to tag the chunk with `tidy: false`, but I have not done that here.

```
## Breaking up a string:

b <- "Statistics at UC Berkeley: We are a community engaged in research
 and education in probability and statistics. In addition to developing
fundamental theory and methodology, we are actively"

## Breaking up a comment:

## Statistics at UC Berkeley: We are a community engaged in research and
## education in probability and statistics. In addition to developing
## fundamental theory and methodology, we are actively

## Breaking up code lines:

vecWithALongName = rnorm(100)
a <- length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) +
    vecWithALongName * vecWithALongName, na.rm = TRUE))
a <- length(mean(5 * vecWithALongName + vecWithALongName)) # this is a comment that
    ## goes over the line by a good long ways
a <- length(mean(5 * vecWithALongName + vecWithALongName - exp(vecWithALongName) +
    vecWithALongName, na.rm = TRUE)) # this is a comment that goes over the line
    ## by a good long long long long long long long long ways
```

7.2 Python code

In Python, there is similar trouble with lines overflowing in PDF output too.

```
# This overflows the page:

b = "asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla lakjsdf aljdkfad kljafda kaljdf a
print(b)
```

```
asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla lakjsdf aljdkfad kljafda kaljdf afdlkj
```

```
# This code overflows the page:

zoo = {"lion": "Simba", "panda": None, "whale": "Moby", "numAnimals": 3, "bear": "Yogi", "ki
print(zoo)
```

```
{'lion': 'Simba', 'panda': None, 'whale': 'Moby', 'numAnimals': 3, 'bear': 'Yogi', 'killer wh
```

To fix the issue, we can use the frontmatter settings noted at the start of this section, or we can manually break the code into multiple lines. However long output still overflows. One workaround is only to print out portions of an object such that what is printed doesn't overflow

```
zoo = {"lion": "Simba", "panda": None, "whale": "Moby",
       "numAnimals": 3, "bear": "Yogi", "killer whale": "shamu",
       "bunny:": "bugs"}
print(zoo)
```

```
{'lion': 'Simba', 'panda': None, 'whale': 'Moby', 'numAnimals': 3, 'bear': 'Yogi', 'killer wh
```

Long comments overflow as well, but you can always manually break into multiple lines.

```
# asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla lakjsdf aljdkfad kljafda kaljdf afdll

# asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla lakjsdf aljdkfad
# kljafda kaljdf afdlkja lkajdfsa lajdfa adlfjaf jkladf afdl
```

7.3 bash code

In bash, we have similar problems with lines overflowing in PDF output, but bash allows us to use a backslash to break lines of code. However that strategy doesn't help with long lines of output.

```
echo "Statistics at UC Berkeley: We are a community engaged in research and education in prob

echo "Second try: Statistics at UC Berkeley: We are a community engaged \
in research and education in probability and statistics. In addition to \
developing fundamental theory and methodology, we are actively" \
>> tmp.txt

cat tmp.txt
```

```
Statistics at UC Berkeley: We are a community engaged in research and education in probabilit
Second try: Statistics at UC Berkeley: We are a community engaged in research and education i
```

We also have problems with long comments, so we would need to manually format them.

Here is a long comment line that overflows in PDF:

```
# asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla lakjsdf aljdkfad kljafda kaljdf afdll
```

Instead manually break the comment into multiple lines:

```
# asdl lkjsdf jklsdf kladfj jksfd alkfd klasdf klad kla
# lakjsdf aljdkfad kljafda kaljdf afdlkja lkajdfsa lajdfa
# adlfjaf jkladf afdl
```

8 References

We'll just see how you use BibTeX style references. Banerjee et al. (2008) proposed a useful method. This was confirmed (Cressie and Johannesson 2008).

Note the indication of the `refs.bib` file in the initial lines of this document so that the bibliographic information for these citations can be found.

The list of references is placed at the end of the document. You'd presumably want a section header like this:

Literature cited

Banerjee, S., A. E. Gelfand, A. O. Finley, and H. Sang. 2008. "Gaussian Predictive Process Models for Large Spatial Data Sets." *Journal of the Royal Statistical Society B* 70 (4): 825–48.

Cressie, N., and G. Johannesson. 2008. "Fixed Rank Kriging for Very Large Spatial Data Sets." *Journal of the Royal Statistical Society B* 70 (1): 209–26.