Preparing high quality reports

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August 21, 2022

Aside from statistical methodology and programming, another goal of STAT 9610 is to teach you how to produce high-quality reports. This skill is essential to successfully communicating the results of your research, e.g. in the form of a manuscript submitted for publication. Therefore, each submitted homework and exam will be held to a high standard of presentation, which will be evaluated and will comprise a small part of your grade. Below are guidelines on producing high-quality reports, broken down by their components: text, code, figures, and tables.

1 Text

Your prose should be clear and concise. Use references to refer to equations, figures, and tables.

2 Code

Your code should be commented and easy to read. Make sure that your code does not exceed the width of the page, like this:

```
# a line that exceeds the width of the page
tibble(x = 1:100, y = 5*x + rnorm(100, sd = 100)) %>% filter(x < 80) %>% summarise(sample_corre
```

To avoid such long lines of code, make sure your code does not reach the vertical line in the right-hand side of your RStudio editor. Insert line breaks appropriately to make your code more readable:

```
# appropriate line breaks added
tibble(x = 1:100, y = 5*x + rnorm(100, sd = 100)) %>%  # generate data
  filter(x < 80) %>%                                   # subset data
  summarise(sample_correlation = cor(x, y))            # evaluate sample corr.
```

3 Figures

Figures are very important tools to convey information to readers, and they should be constructed thoughtfully. Please read Chapter 28 of R for Data Science, which is a good reference for producing high-quality figures. Here we discuss some of the most important elements.

Sizing. The **aspect ratio** (i.e. ratio of width to height) of your plots is consistent with their content; e.g. box plots are usually relatively narrow, and scatter plots often make sense with equal aspect ratios.

Once you have created a plot in R, you need to export it to include it in your LaTeX report. For example, suppose we have the plot `p` defined as below:

```
test_data <- tibble(x = rnorm(10), y = rnorm(10))
p <- test_data %>% ggplot(aes(x = x, y = y)) + geom_point() + theme_bw()
```

You should save it as a PDF via `ggsave`:

```
ggsave(plot = p,
       filename = "figures-and-tables/test_plot.pdf",
       device = "pdf",
       width = ???,
       height = ???)
```

and then insert it into the LaTeX report via `\includegraphics`:

```
\begin{figure}[h!]
\centering
\includegraphics{figures-and-tables/test_plot.pdf}
\caption{A test plot.}
\label{fig:test-plot}
\end{figure}
```

Here, the question marks should be the width and height of the figure, in inches. Choose these to get a reasonable aspect ratio for the plot and a reasonable overall plot size. Figures 1, 2, and 3 consider the width and length of the figure to be 1 inch, 2.5 inches, and 5 inches, respectively. The medium-sized plot (Figure 2) appears to be the most sensible choice.

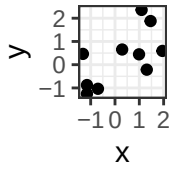

Figure 1: The plot saved as 1in by 1in.

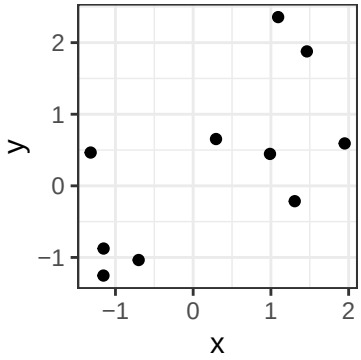

Figure 2: The plot saved as 2in by 2in.

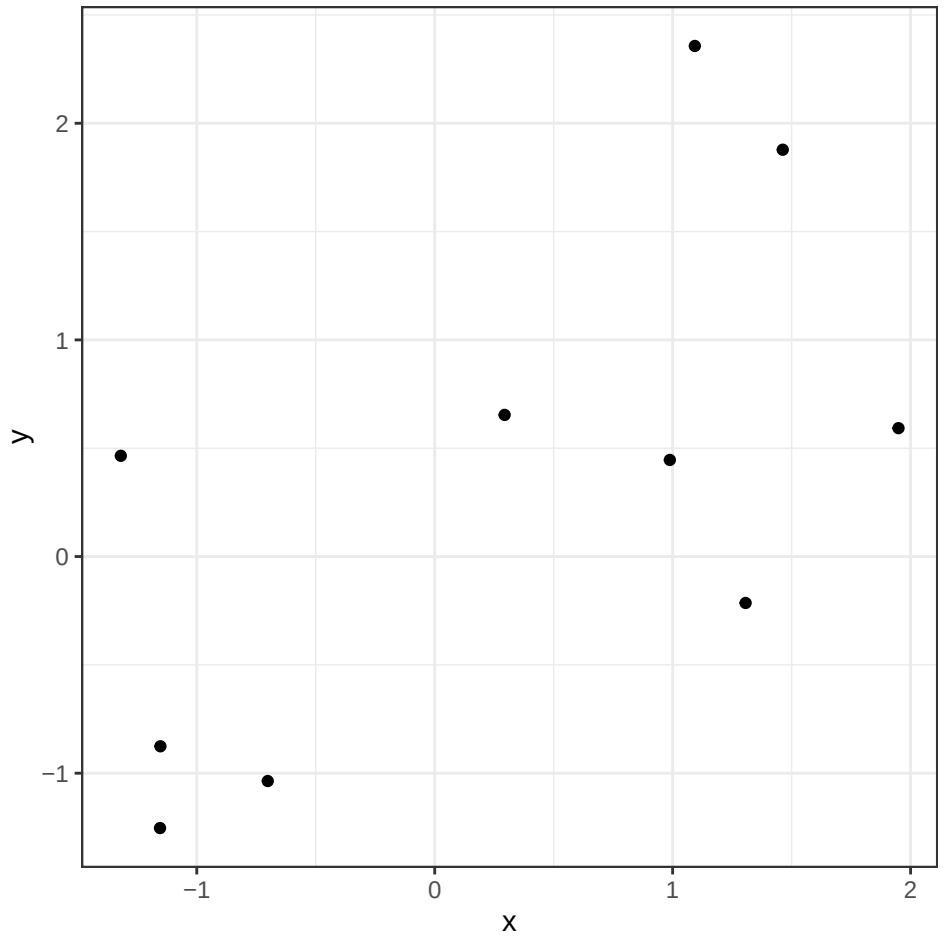

Figure 3: The plot saved as 5in by 5in.

Titles. Each plot should include informative axis and legend titles. For example, consider the code below (drawn from R4DS Chapter 28), which produces the plot in Figure 4.

```
# a plot without clear axis and legend titles
p <- mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  theme_bw()

# save plot
ggsave(plot = p,
       filename = "figures-and-tables/cars-unlabeled.pdf",
       device = "pdf",
       width = 5,
       height = 3.75)
```

This is a plot of fuel efficiency versus engine displacement for various types of cars, but the axis and legend labels on the plot do not make this very clear. We can easily add informative titles to

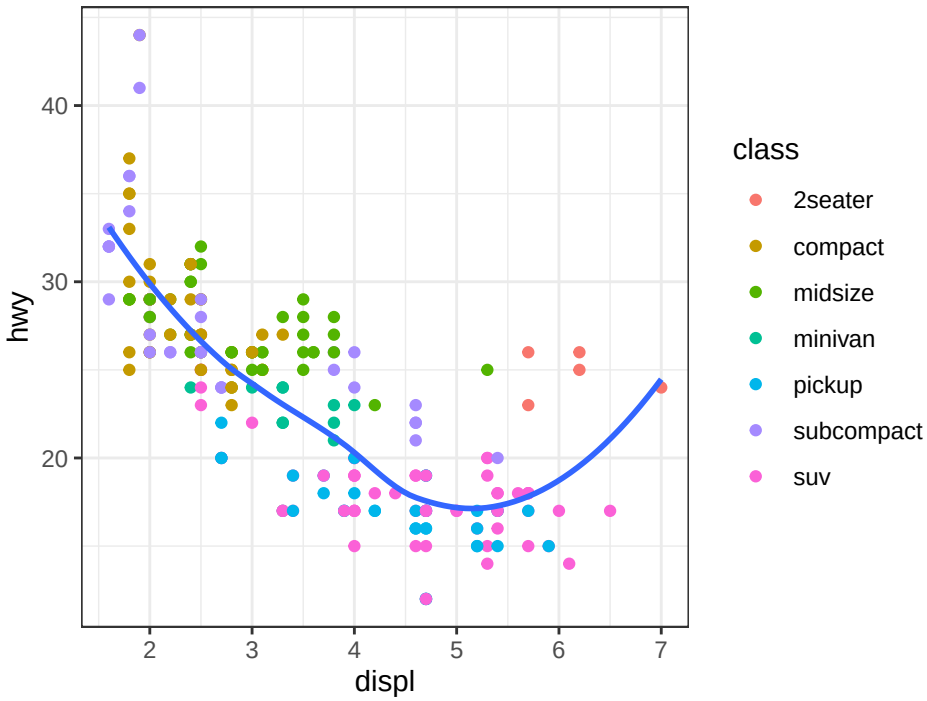

Figure 4: A plot without clear titles.

this plot using `labs`, resulting in Figure 5, which is much easier to understand.

```
# a plot with clear axis and legend titles
p <- mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  labs(
    x = "Engine displacement (liters)",
    y = "Highway fuel economy (miles per gallon)",
    colour = "Car type"
  ) +
  theme_bw()

# save plot
ggsave(plot = p,
       filename = "figures-and-tables/cars-labeled.pdf",
       device = "pdf",
       width = 5,
       height = 3.75)
```

Plots might or might not need overall titles; often the axis titles speak for themselves and the message of the plot can be conveyed in the caption (as in Figure 5.) To add plot titles if necessary, use the `title` argument to `labs()`.

If applicable, axis titles should also include the units of measurement, e.g. liters or miles

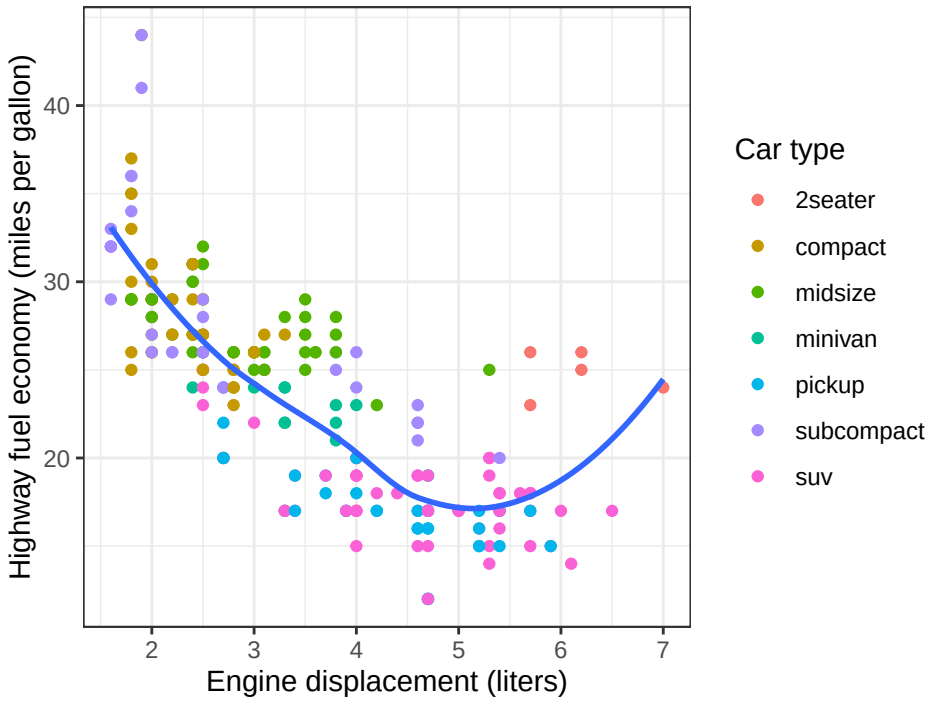

Figure 5: (A plot with clear axis and legend titles). Fuel efficiency generally decreases with engine size; two-seaters (sports cars) are an exception because of their light weight.

per gallon as in Figure 5. If axis titles involve mathematical formulas, these should be typeset appropriately. The code below (drawn from R4DS Chapter 28) and Figure 6, which it produces, illustrate how to do this. More examples can be found at `?plotmath`.

```
# a plot illustrating how to include formulas in axis titles
p = tibble(x = runif(10),
       y = runif(10)) %>%
  ggplot(aes(x, y)) +
  geom_point() +
  labs(x = quote(sum(x[i] ^ 2, i == 1, n)),
       y = quote(alpha + beta + frac(delta, theta))) +
  theme_bw()

# save the plot
ggsave(plot = p,
       filename = "figures-and-tables/fig-formulas.pdf",
       device = "pdf",
       width = 2.5,
       height = 2.5)
```

Captions. Figures should have informative captions to help readers understand what information is displayed and how to interpret it.

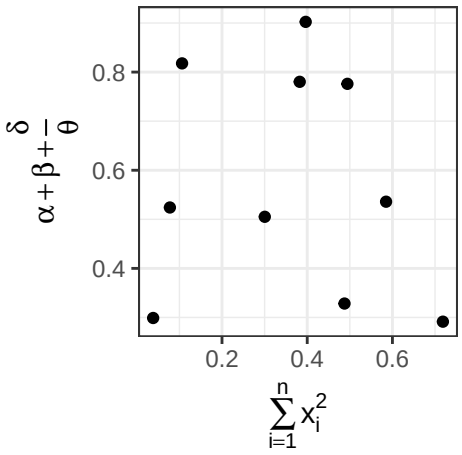

Figure 6: An illustration of using formulas in axis titles.

Layout. Sometimes, two or more plots make sense to present together in a single figure. This can be accomplished in two ways. If the different plots convey the same type of information but for different slices of the data, then `facet_grid` and `facet_wrap` are the best way of laying out these plots. For example, the code below and Figure 7 illustrates `facet_wrap` for the `mpg` data used in Figures 4 and 5.

```
# illustrate how to use facet_wrap to create a multi-panel plot
p = mpg %>%
  filter(class %in%
           c("2seater", "compact", "midsize")) %>%  # select 3 classes of cars
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  facet_wrap(class ~ .) +                           # separate panels per class
  labs(
    x = "Engine displacement (liters)",
    y = "Highway fuel economy\n(miles per gallon)", # line break in axis title
  ) +
  theme_bw()

# save the plot
ggsave(plot = p,
       filename = "figures-and-tables/facet-wrap.pdf",
       device = "pdf",
       width = 5.5,
       height = 2.25)
```

If the plots convey different types of information, then they should be created separately and then concatenated together using `plot_grid` from the `cowplot` package. An example is shown below and in Figure 8. Note that the figure caption should reference the subpanels by their labels (in this case, a and b).

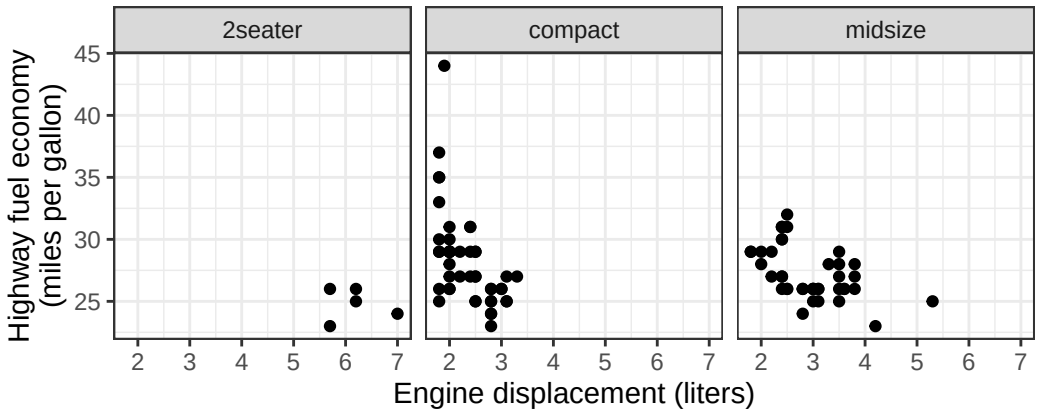

Figure 7: An illustration of using `facet_wrap` to create a multi-panel plot.

```
# illustration of using cowplot to concatenate multiple plots
library(cowplot)

# first plot: box plot of fuel economy by car type
p1 = mpg %>%
  mutate(class =                          # re-order car classes by fuel economy
           fct_reorder(class, hwy)) %>%
  ggplot(aes(x = class, y = hwy, fill = class)) +
  geom_boxplot() +
  labs(
    x = "Car type",
    y = "Highway fuel economy\n(miles per gallon)"
  ) +
  theme_bw() +
  theme(legend.position = "none",         # remove legend and x axis text because
        axis.text.x = element_blank())    #  information present in second plot

# second plot: scatter plot of fuel economy versus car type
p2 = mpg %>%
  mutate(class =                          # re-order car classes by fuel economy
           fct_reorder(class, hwy)) %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  labs(
    x = "Engine displacement (liters)",
    colour = "Car type"
  ) +
  theme_bw() +
  theme(axis.title.y = element_blank())  # remove y axis title because already
                                         #  present in the first plot
```

```
# use plot_grid from cowplot to concatenate the two plots
p = plot_grid(p1,
              p2,
              labels = "auto",      # generate labels for subplots
              rel_widths = c(1,2), # specify relative widths
              align = "h")          # how to align subplots

# save the plot
ggsave(plot = p,
       filename = "figures-and-tables/cowplot-demo.pdf",
       device = "pdf",
       width = 5,
       height = 2.5)
```

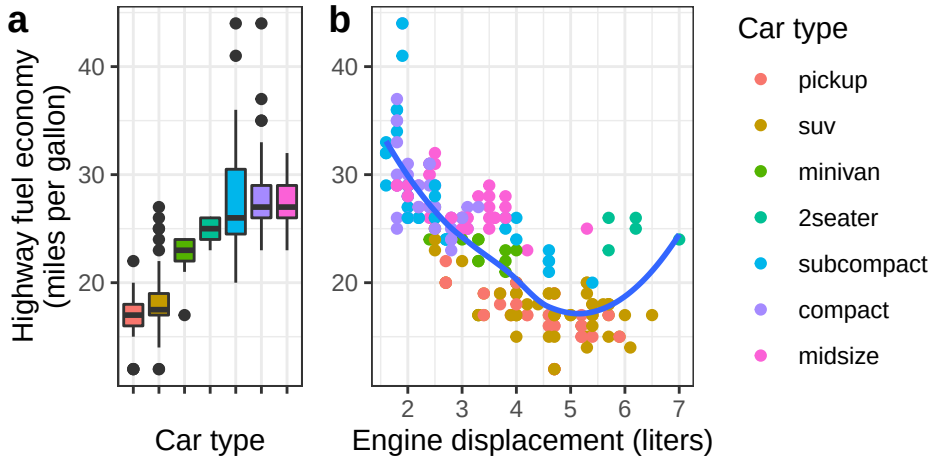

Figure 8: (An illustration of using `cowplot` to create a multi-panel plot.) Relationships between highway fuel economy and car type (a) and engine displacement (b).

4 Tables

The two tools used to create nice tables are `kable` (requiring the `knitr` and `kableExtra` packages) and `stargazer` (from the `stargazer` package). `kable` is useful for printing general rectangular tables, while `stargazer` is useful for printing regression outputs. Both export tables as LaTeX code, which can be imported in a LaTeX document using `\include`. Problem 3 of the sample homework shows how to create tables using `kable` and `stargazer`, and the corresponding LaTeX document shows how to include the tables produced in your report.

As far as presentation quality for tables, many of the principles of creating high-quality figures carry over, e.g. using informative captions and column names.