Medartis Wrist Plates

Experiment 2 - bending and shear matched

2024-07-23

setup

Load any needed libraries and define some constants.

```r
library(dplyr) # for manipulating dataframes
library(ggplot2) # for plotting

# If you don't have bluer install it with
# inatall.packages("devtools")
# devtools::install_github(repo = "yadbor/bluer")
library(bluer) # routines for analysing mechanical test data


data_root <- here::here("data-raw", "Experiment 2", "Results", "VIC-3D data")

data_col_names <- "File Number,U [mm],V [mm],W [mm],Time_1,position,load"
data_cols <- stringr::str_split_1(data_col_names, ",")
```

read the data files

Get all the `.csv` file names under the `data_root` folder and store them in a `list`.

Then run the list of file paths names through a pipeline that does the following:

1. Name every list element with the `basename` from the path
   (i.e. just the file name with no path or extension)
2. Read each .csv file into the list as a dataframe
3. Keep only the wanted columns in each dataframe
4. Stack the read dataframes, adding the names from the list as a column

```
# Find all .csv files under the data_root
file_path <- list.files(path = data_root, pattern = "*.csv",
                        full.names = TRUE, recursive = TRUE)

all_results <- file_path |>
  setNames(basename(file_path)) |> # name each item in the list with its basename
  purrr::map( \(df) readr::read_csv(df, show_col_types = FALSE) |>
                  select(data_cols)
              ) |>
  bind_rows(.id = "filename")      # bind together, adding a column for the name
```

`all_results` is now a big dataframe (actually a tibble) holding all the results from all tests, labelled with their file name. This will work for studies like this one where all the meta-data are in the file names. For some studies some of the meta-data can be in the folder name as well. In those cases the final folder name can be extracted using `basename(pathname(full_path))`.

extract test information

The filenames have the plate type, id and repeat encoded as:

"{Long|Short} Plate {id} T{repeat}_Data.csv"

Extract these into separate columns to identify each test. Because the filenames don't have clean delimiters use a regex to break them up.

Some names have special issues, like the two that were repeated (T1.2 & T2.2). Clean those up here as well.

```
all_results <- all_results |>
  tidyr::separate_wider_regex(cols = filename,
                              patterns = c(plate = "^\\w+", "\\D*",
                                           id = "\\d+", "\\s*T",
                                           rep = "[\\d\\.]+", ".*"),
                              cols_remove = FALSE
                              ) |>
  # Deal with special cases.
  # In this study, T1.2 and T2.2 replace T1 and T2
  mutate(rep = stringr::str_remove(rep, "\\..*")) # delete everything after "."
```

Replace the column names with names that are easier to manipulate in code but still convey their purpose

```r
all_results <- all_results |>
  rename(frame = `File Number`,
         u = `U [mm]`, v = `V [mm]`, w = `W [mm]`,
         time = `Time_1`)
```

save clean data

Write the cleaned data to a `.csv` file before starting the analysis.

```r
all_results |>
  readr::write_csv(file = here::here("data", "all_results.csv"))
```

analyse cycles

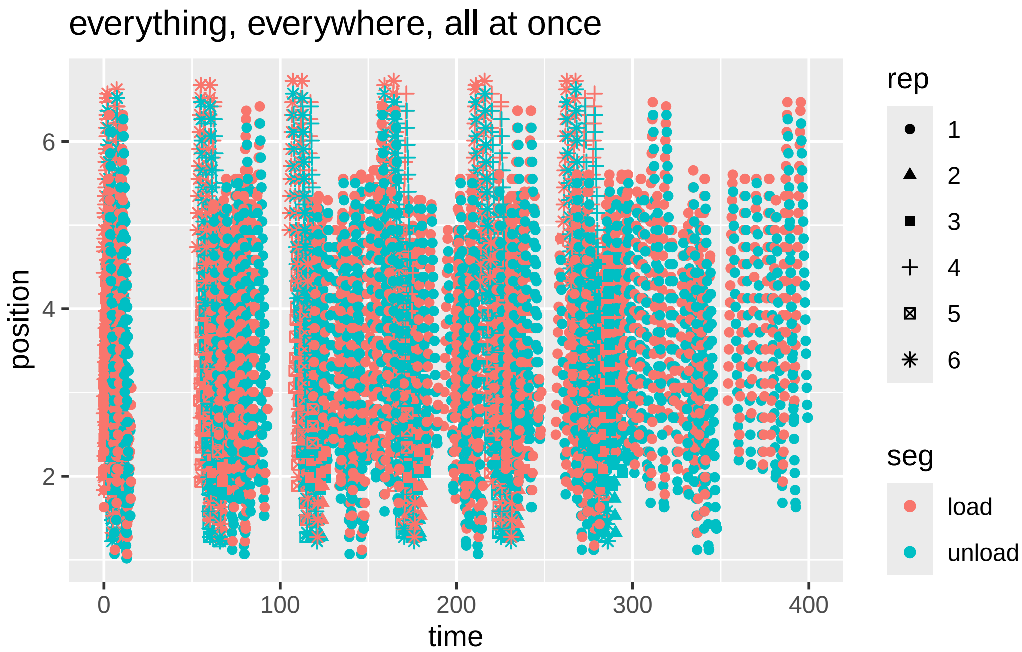
Each test has multiple load-unload cycles. Data are recorded on the 9th and 10th cycles, and this is repeated every 10 cycles up to a total of 60 cyles. We are interested in the loading part of each cycle.

Divide test into cycles by finding peaks and troughs. The loading phase is the one going towards a peak, and the unloading phase is towards a trough.

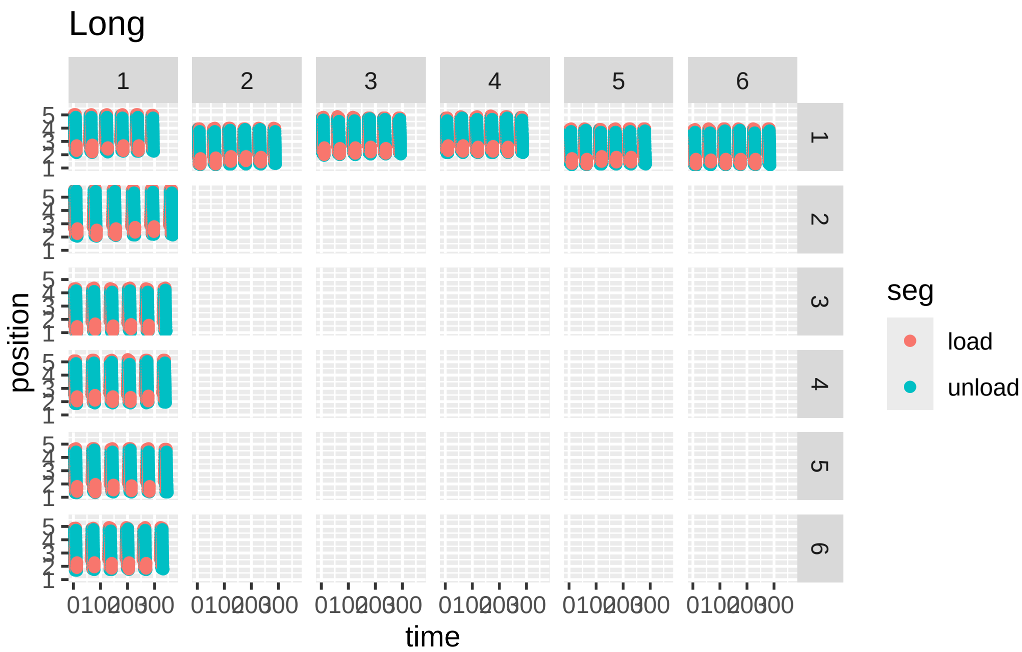
The `bluer` package has routines for finding peaks and labelling cycles and phases.

But first, as these tests are all in compression, the load and position are all negative. Invert them both so that graphs read better for most people.

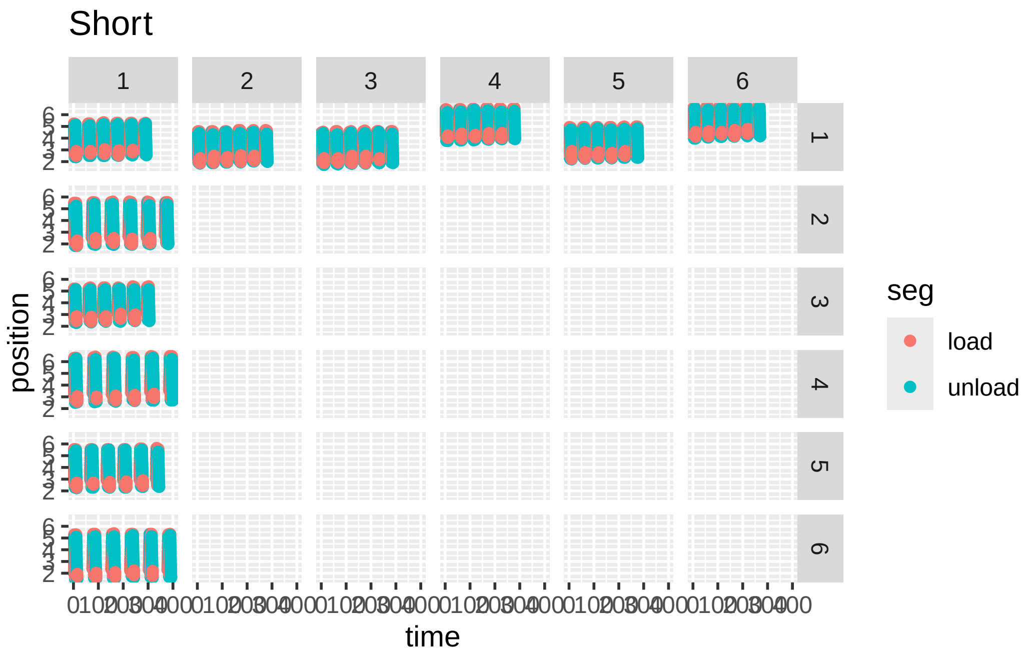
```r
cycles <- all_results |>
  mutate(position = -1.0 * position, load = -1.0 * load) |> # Invert these axes
  group_by(plate, id, rep) |> # group each test
  mutate(as_tibble(bluer::label_cycles(position))) |> # and label the cycles
  mutate(cycle = factor(cycle)) |> # Make the cycle a factor for easier plotting
  mutate(uid = paste0(plate,id,rep,cycle)) # uniquely identify each cycle

# Check what we have done
cycles |> ggplot() +
  aes(x = time, y = position, colour = seg, group = rep) +
  geom_point(aes(shape = rep)) +
  facet_grid(rows = vars(plate), cols = vars(id)) |>
  labs(title = "everything, everywhere, all at once")
```




```
# that plot was crowded, so do separate ones for each plate
#

cycles |>
    filter(plate == "Long") |>
    ggplot() +
    aes(x = time, y = position, colour = seg, group = rep) +
    geom_point() +
    facet_grid(rows = vars(id), cols = vars(rep)) +
    labs(title = "Long")
```

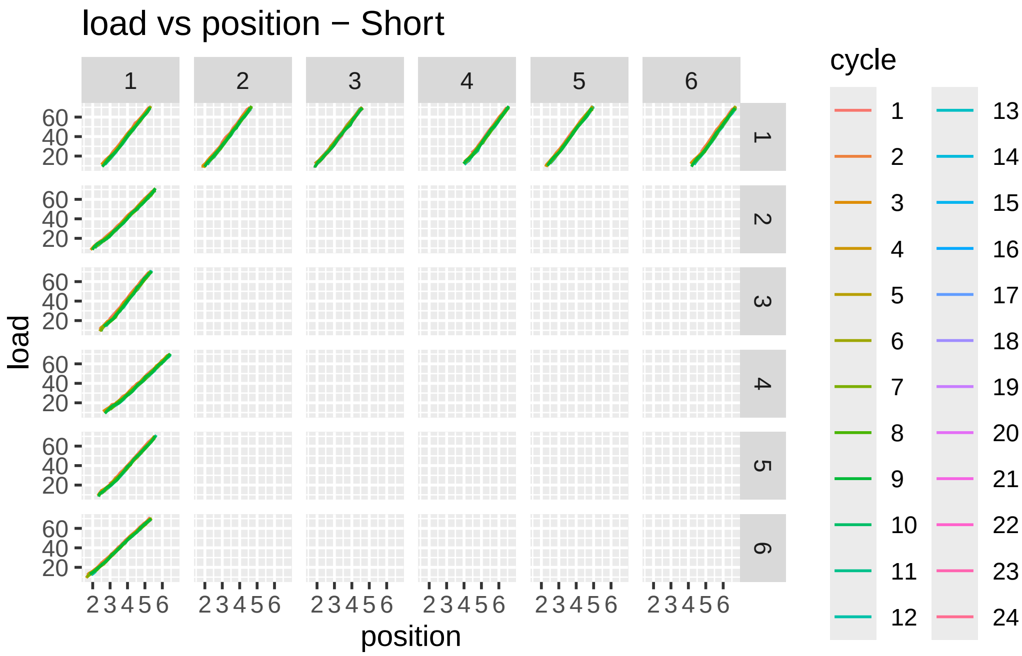



```r
cycles |>
    filter(plate == "Short") |>
    ggplot() +
    aes(x = time, y = position, colour = seg, group = rep) +
    geom_point() +
    facet_grid(rows = vars(id), cols = vars(rep)) +
    labs(title = "Short")
```

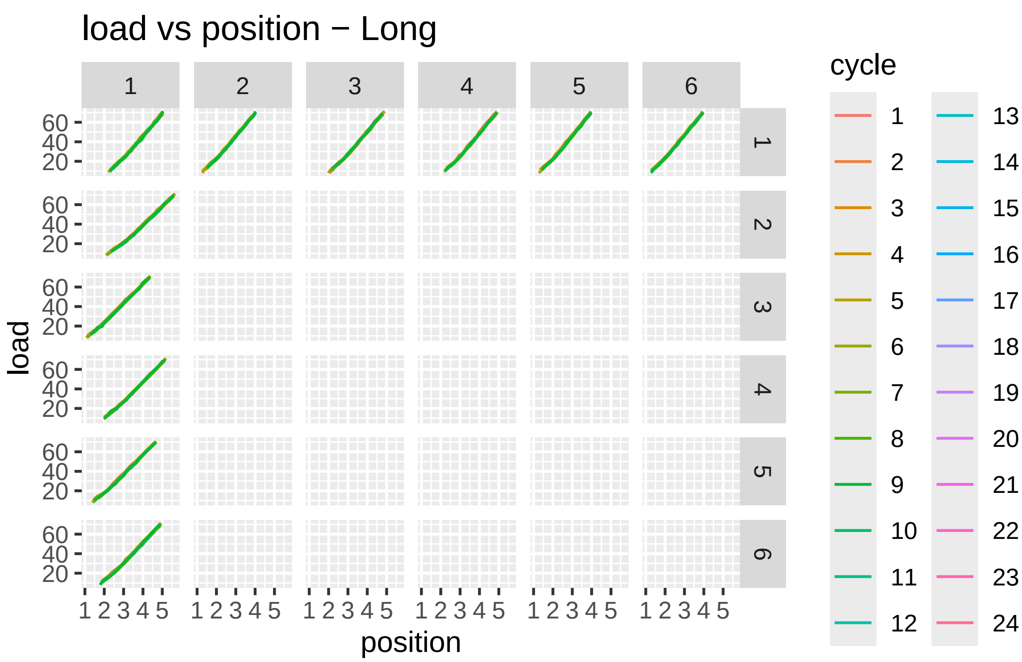


Plot just the loading portion of each cycle, as load vs position.

```
loading <- cycles |>
    filter(seg == "load")

loading |>
    filter(plate == "Short") |>
    ggplot() +
    aes(x = position, y = load, colour = cycle, group = uid) +
    geom_line() +
    facet_grid(rows = vars(id), cols = vars(rep)) +
    labs(title = "load vs position - Short")
```




```
loading |>
    filter(plate == "Long") |>
    ggplot() +
    aes(x = position, y = load, colour = cycle, group = uid) +
    geom_line() +
    facet_grid(rows = vars(id), cols = vars(rep)) +
    labs(title = "load vs position - Long")
```



analysis

To get the stiffness of each test we fit a linear model by least squares.

```
loading_models <- loading |>
  #group_by(uid) |>
  group_by(plate, id, rep, cycle) |>
  summarise(
    model = list(
      lm(load ~ position, data = pick(everything()))
    )
  )
```

```
`summarise()` has grouped output by 'plate', 'id', 'rep'. You can override
using the `.groups` argument.
```

```
loading_models |>
  mutate(glance = purrr::map(model, broom::glance))|>
  tidyr::unnest(glance)
```

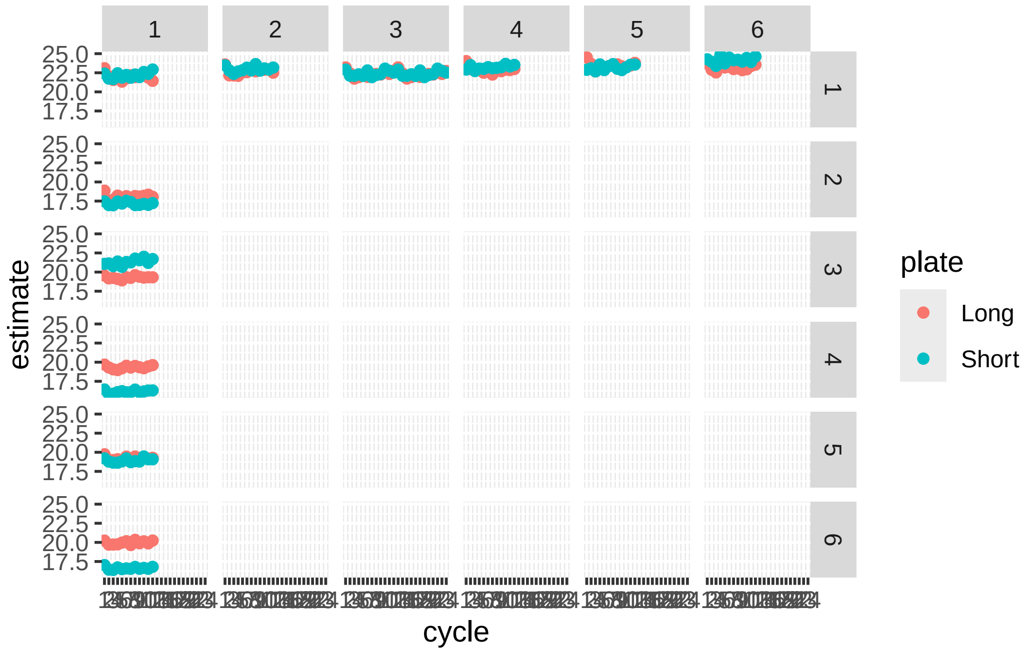
```
# A tibble: 288 x 17
```

```
# Groups:   plate, id, rep [22]
   plate id    rep   cycle model  r.squared adj.r.squared sigma statistic
   <chr> <chr> <chr> <fct> <list>     <dbl>         <dbl> <dbl>     <dbl>
 1 Long  1     1     1     <lm>       0.996         0.996 1.05      2776.
 2 Long  1     1     2     <lm>       0.996         0.996 1.22      2981.
 3 Long  1     1     3     <lm>       0.996         0.995 1.27      3034.
 4 Long  1     1     4     <lm>       0.998         0.997 0.934     4936.
 5 Long  1     1     5     <lm>       0.995         0.995 1.37      2824.
 6 Long  1     1     6     <lm>       0.997         0.997 1.01      4165.
 7 Long  1     1     7     <lm>       0.997         0.996 1.14      3162.
 8 Long  1     1     8     <lm>       0.998         0.998 0.781     7017.
 9 Long  1     1     9     <lm>       0.995         0.995 1.38      2797.
10 Long  1     1     10    <lm>       0.997         0.997 1.08      3903.
# i 278 more rows
# i 8 more variables: p.value <dbl>, df <dbl>, logLik <dbl>, AIC <dbl>,
#   BIC <dbl>, deviance <dbl>, df.residual <int>, nobs <int>
```

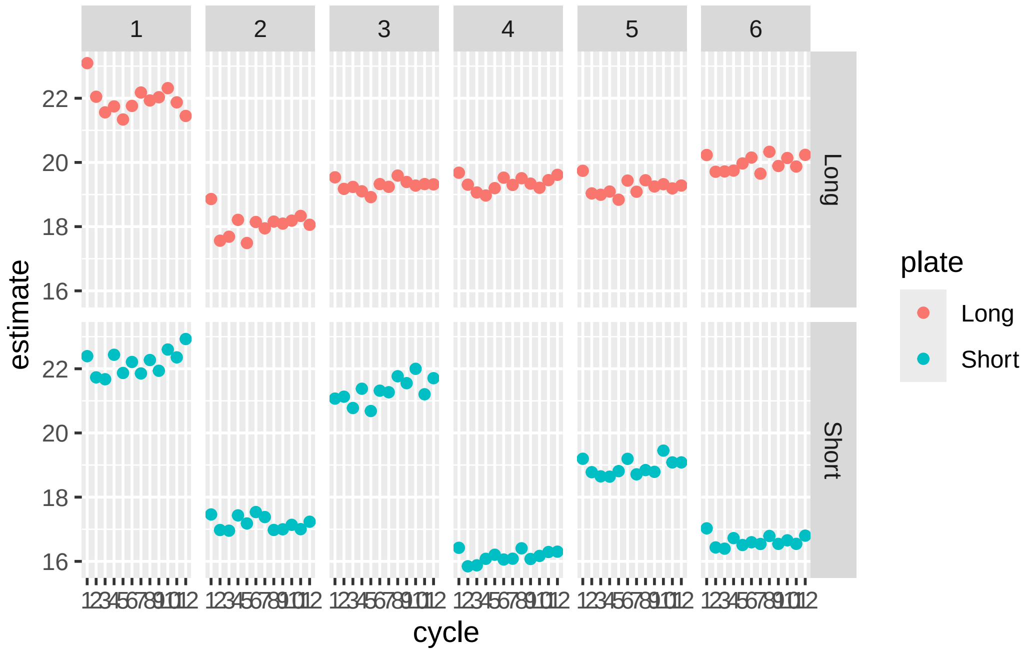
```r
# Extract the slope components of the models
lm_fits <- loading_models |>
  mutate(tidy = purrr::map(model, broom::tidy)) |>
  tidyr::unnest(tidy) |>
  filter(term != '(Intercept)')

lm_fits
```

```
# A tibble: 288 x 10
# Groups:   plate, id, rep [22]
   plate id    rep   cycle model  term     estimate std.error statistic  p.value
   <chr> <chr> <chr> <fct> <list> <chr>       <dbl>     <dbl>     <dbl>    <dbl>
 1 Long  1     1     1     <lm>   position     23.1     0.438      52.7 1.47e-13
 2 Long  1     1     2     <lm>   position     22.0     0.404      54.6 9.38e-16
 3 Long  1     1     3     <lm>   position     21.6     0.391      55.1 8.56e-17
 4 Long  1     1     4     <lm>   position     21.7     0.310      70.3 4.59e-17
 5 Long  1     1     5     <lm>   position     21.3     0.402      53.1 1.36e-16
 6 Long  1     1     6     <lm>   position     21.8     0.337      64.5 1.27e-16
 7 Long  1     1     7     <lm>   position     22.2     0.394      56.2 6.95e-15
 8 Long  1     1     8     <lm>   position     21.9     0.262      83.8 5.59e-18
 9 Long  1     1     9     <lm>   position     22.0     0.417      52.9 1.45e-16
10 Long  1     1     10    <lm>   position     22.3     0.357      62.5 1.87e-16
# i 278 more rows
```

```r
lm_fits |> ggplot() +
  aes(x= cycle, y = estimate, colour = plate) +
  geom_point() +
  facet_grid(rows = vars(id), cols = vars(rep))
```




```r
lm_fits |> filter(rep == 1) |> ggplot() +
  aes(x= cycle, y = estimate, colour = plate) +
  geom_point() +
  facet_grid(cols = vars(id), rows = vars(plate))
```



check for effect of cycling

We have six plates, each tested mutiple times, and each test consisting of multiple cycles. To test if the number of cycles is having an effect we need a two way repeated measured ANOVA, because both the tests and the cycles are repeated for each plate.

```
# lm_fits |>
#   summarise(
#     anova = list(aov(estimate ~ rep * cycle + Error(id / (rep * cycle))))
#   )
```