Spectrogram Smoothing

J.P. Meagher

3 October 2017

Call spectrograms are being modelled as functional data objects in this analysis. As such, spectrograms need to be smoothed.

Previous analysis of spectrograms for a Romance language data set used smoothing splines for this task. However, wavelets may be the more appropriate smoothing method in this context.

Here I will attempt to implement wavelet denoising for the spectrograms.

Packages

```
library(batwork)
library(tidyverse)
library(magrittr)
library(RColorBrewer)
```

Data

```
df <- mexican_bat_calls

df <- df %>%
  mutate(time = map(calls, get_spectrogram_details, detail = 'time'), psd = map(calls, get_psd))

observed_frequencies <- get_spectrogram_details(df$calls[[1]], detail = 'freq')
```

Restrict Spectrogram Space

Bats use the frequency band 9-212 kHz for their echolocation calls, and so it is appropriate to restrict spectrograms to this band.

```
band <- observed_frequencies > 9000 & observed_frequencies < 212000

df <- df %>%
  mutate(restricted = map(psd, extract, , band)) %>%
  mutate(restricted = map(restricted, log10)) %>%
  mutate(restricted = map(restricted, multiply_by, 10))
```

```
n <- sample.int(df %>% nrow, 1)
df %>% use_series(restricted) %>% extract2(n) %>% image(col = brewer.pal(9, 'Spectral'))
```

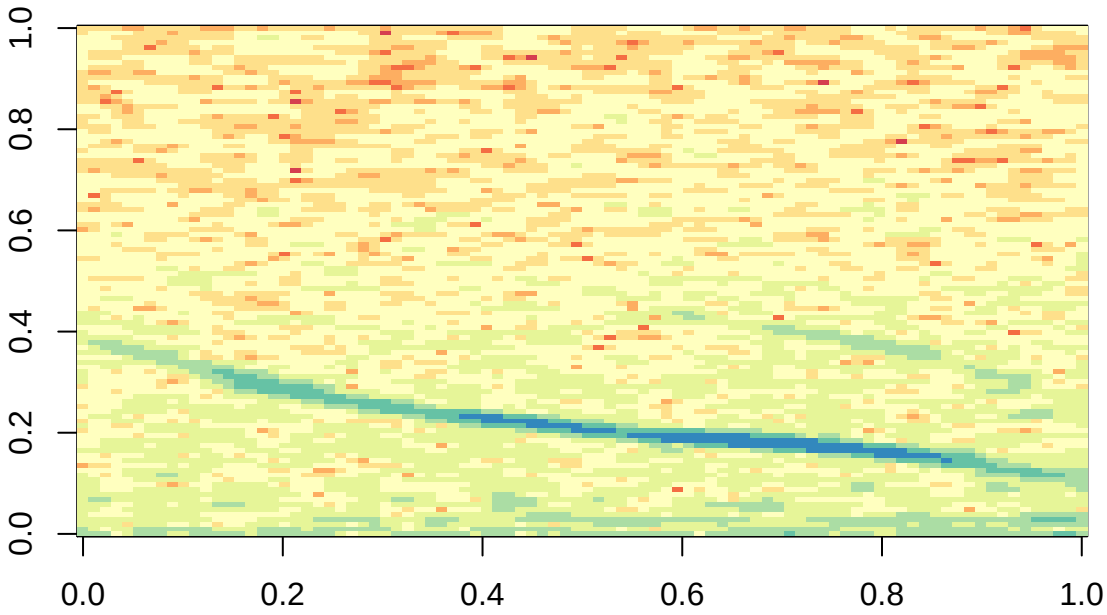

Figure 1: An example of a spectrogram restricted to relevant frequencies.

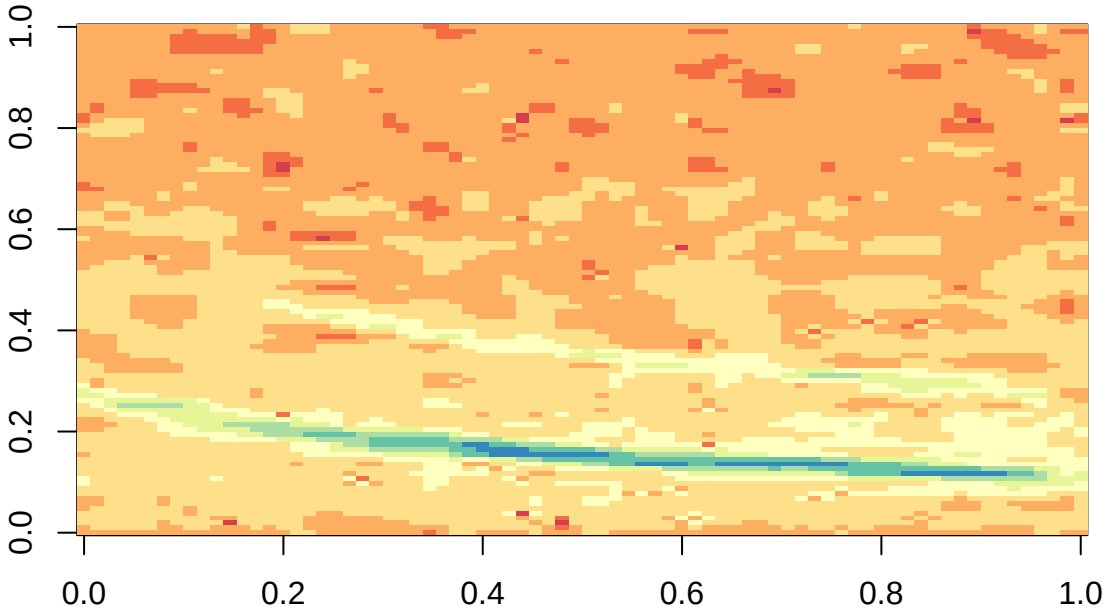

Figure 2: An example of a restricted spectrogram to which wavelet smoothing has been applied.

Wavelet Smoothing

Wavelets can be used for image denoising and as the spectrogram is analagous to an image I will try the same procedure here.

I have encountered some difficulties with the wavelet smoothing. Although it seems to do a relatively good job at producing a smooth underlying function, interpolation does not seem so straightforward as with smoothing splines. Interpolation is important for the surface registration. Perhaps I need to consider a smoothing spline approach.

For the time being, use the wavelet smoothing function and then perform interpolation.

```
df <- df %>%
  mutate(smoothed = map(restricted, waveslim::denoise.dwt.2d, J = 2))
```

```
n <- sample.int(df %>% nrow, 1)
df %>% use_series(smoothed) %>% extract2(n) %>% image(col = brewer.pal(9, 'Spectral'))
```

Interpolation

Having obtained smooth spectrogram surfaces, interpolate so that every surface is reported on a regularised grid.

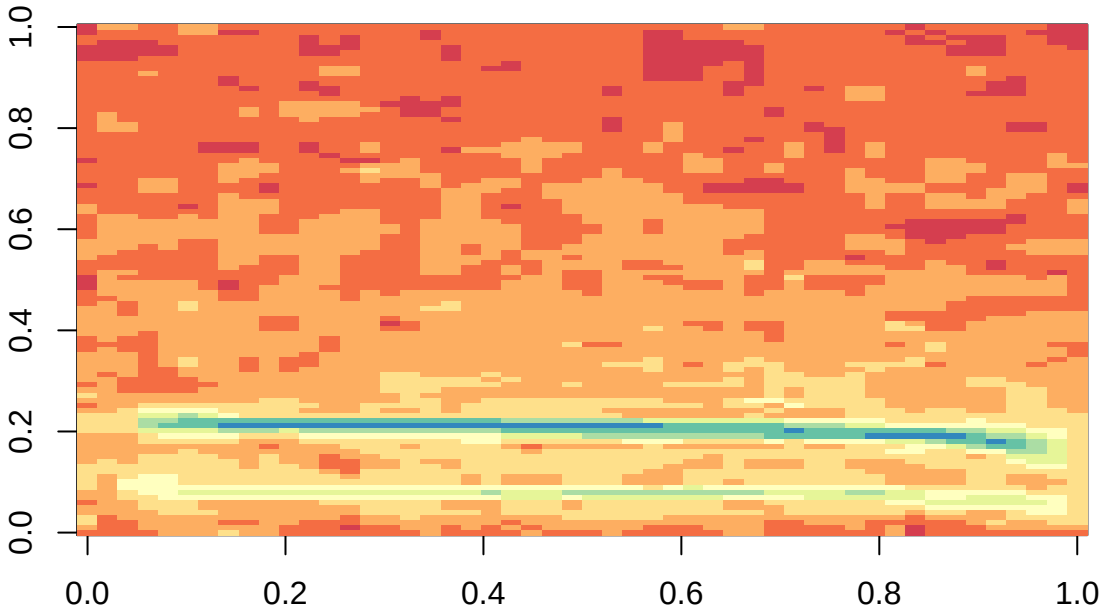

Figure 3: An example of a restricted spectrogram to which wavelet smoothing has been applied mapped to the regularised grid.

```
grid_interpolation <- function(z, n_x = 50L, n_y = 100L){
  x_in <- seq(0, 1, length.out = z %>% nrow)
  y_in <- seq(0, 1, length.out = z %>% ncol)

  x_out <- seq(0, 1, length.out = n_x)
  y_out <- seq(0, 1, length.out = n_y)

  obj <- list(x = x_in, y = y_in, z = z)
  grid.list <- list(x = x_out, y = y_out)

  z_interp <- fields::interp.surface.grid(obj = obj, grid.list = grid.list) %>% extract2('z')

  return(z_interp)
}

df <- df %>%
  mutate(regularised = map(smoothed, grid_interpolation))
```

```
n <- sample.int(df %>% nrow, 1)
df %>% use_series(regularised) %>% extract2(n) %>%
image(col = brewer.pal(9, 'Spectral'))
```

Conclusion

Smoothed spectrogram surfaces on the same regularised grid have been produced and some potential issues highlighted.

- I may have spend some time with the wavelet smoothing step. I have a high level understanding of it and a justification for choosing wavelets over Garcia's method other than just the fact that Garcia's method has not been implemented in R.
- I used a linear interpolation rather than a cubic one. For FDA I would like a smooth estimate of the underlying function. Practically it probably doesn't matter. There is a function in Matlab for cubic interpolation. Is it worth porting to R?