…Modern movies use a lot of mathematics for their computer animations and CGI effects, one of them is what is known under the name *fractals*.

In this post, we will use this technique to create islands with coastlines that look extraordinarily realistic. If you want to do that yourself read on!

I was lucky enough to meet Professor Benoit Mandelbrot, one of the brightest minds of the past century and one of the fathers of *fractal geometry*, in person. One of his papers bears the title “How Long is the Coast of Britain?” where the so-called coastline paradox is being addressed: it basically states that the finer your ruler is the longer your overall result will be, so the coastline of a landmass does not have a well-defined length… an obviously counterintuitive result:

Source: wikimedia

Here we will turn this principle on its head and use it to actually create realistic-looking landmasses with R. The inspiration for this came from chapter 4 “Infinite Detail” of the book “Math Bytes” by my colleague Professor T. Chartier from Davidson College in North Carolina.

The idea is to start with some very simple form, like a square, and add more detail step-by-step. Concretely, we go through every midpoint of our ever more complex polygon and shift it by a random amount. Because the polygon will be getting more and more intricate we have to adjust the absolute amount by which we shift the respective midpoints. That’s about all… have a look at the following code:

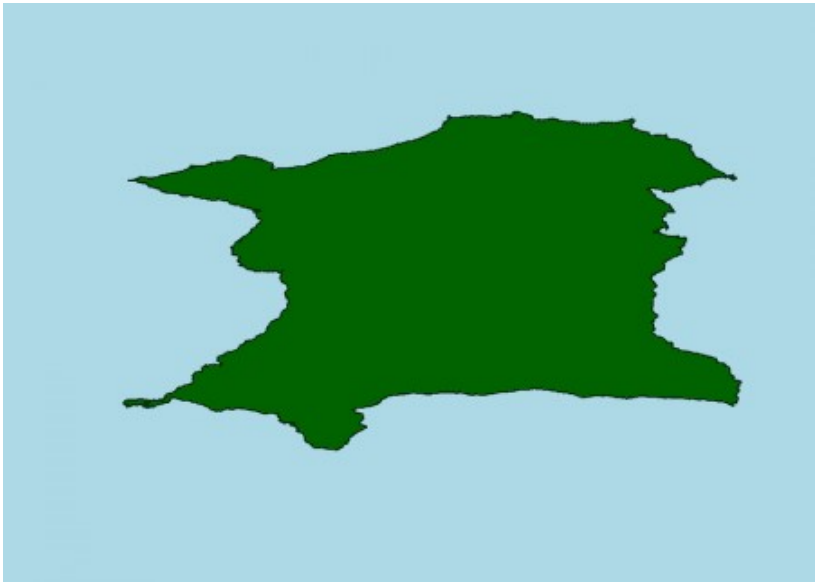
```
# define square
x <- c(0, 16, 16, 0, 0)
y <- c(0, 0, 16, 16, 0)

# function for generating random offsets of midpoints, change e.g. limit for
your own experiments
realistic <- function(n, k) {
  limit <- 0.5^k * 10
  runif(n, -limit, limit)
}

# function for calculating all midpoints of a polygon
midpoints <- function(x) {
  na.omit(filter(x, rep(1/2, 2)))
}

island <- function(x, y, iter = 10, random = realistic) {
  # suppress "number of columns of result is not a multiple of vector length"-
warnings because recycling is wanted here
```

```
  oldw <- getOption("warn")
  options(warn = -1)

  for (i in 1:iter) {
    # calculate midpoints of each line segment
    x_m <- as.numeric(midpoints(x))
    y_m <- as.numeric(midpoints(y))

    # shift midpoint by random amount
    x_m <- x_m + random(length(x_m), i)
    y_m <- y_m + random(length(y_m), i)

    #insert new midpoints into existing coordinates of polygon
    x_n <- c(rbind(x, x_m))
    x_n <- x_n[-length(x_n)]
    y_n <- c(rbind(y, y_m))
    y_n <- y_n[-length(y_n)]

    x <- x_n
    y <- y_n
  }
  options(warn = oldw)
  list(x = x, y = y)
}

plot_island <- function(coord, island_col = "darkgreen", water_col =
"lightblue") {
  oldp <- par(bg = water_col)
  plot(coord$x, coord$y, type = "n", axes = FALSE, frame.plot = FALSE, ann =
FALSE)
  polygon(coord$x, coord$y, col = island_col)
  par(oldp)
}
```

Perhaps one thing is worth mentioning concerning the interaction of the functions: `island` receives the `realistic` function as an argument, which is a very elegant way of modularizing the code in case you want to try different randomizing functions. This extraordinary feature is possible because R is a *functional programming language* where functions are *first-class citizens* (for an introduction on this see here: Learning R: A gentle introduction to higher-order functions).

But now for some serious terra-forming:

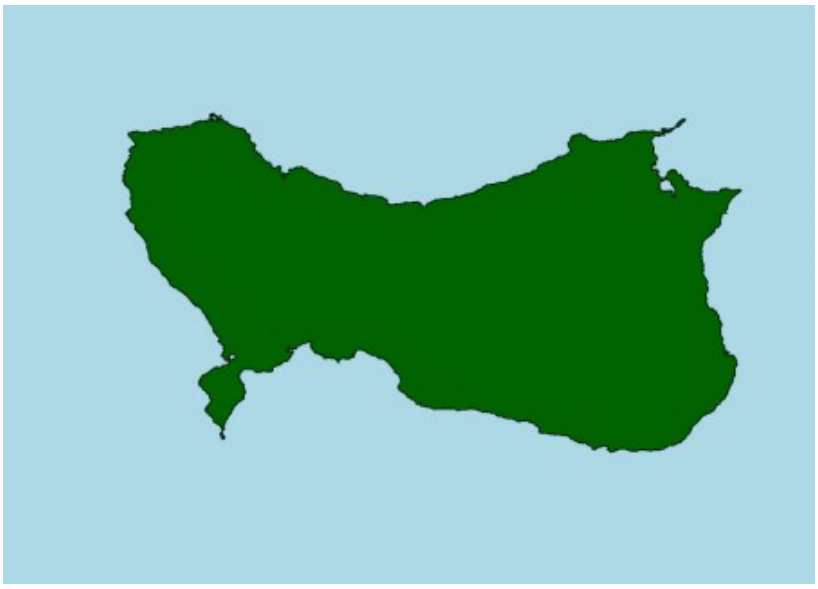
```
set.seed(1) # for reproducability
coord <- island(x, y)
plot_island(coord)
```



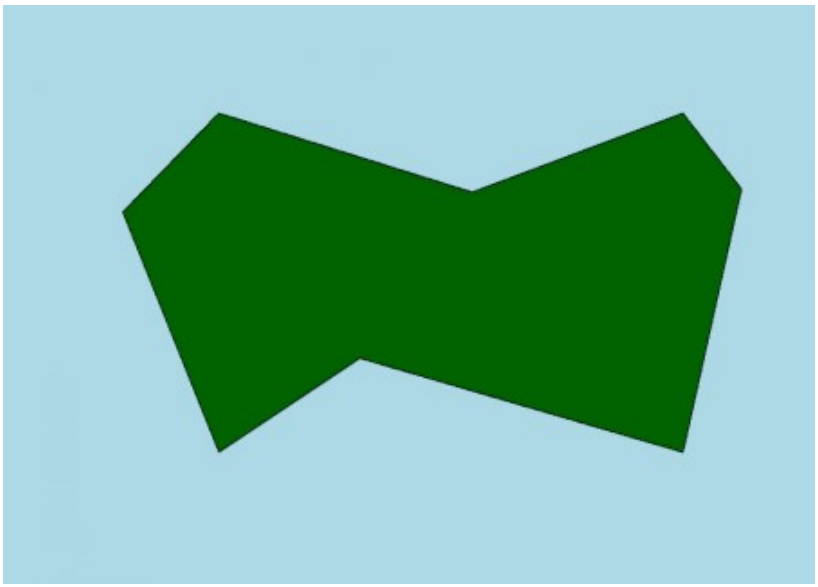
```
set.seed(3)
coord <- island(x, y)
plot_island(coord)
```

We can also observe the process step-by-step:

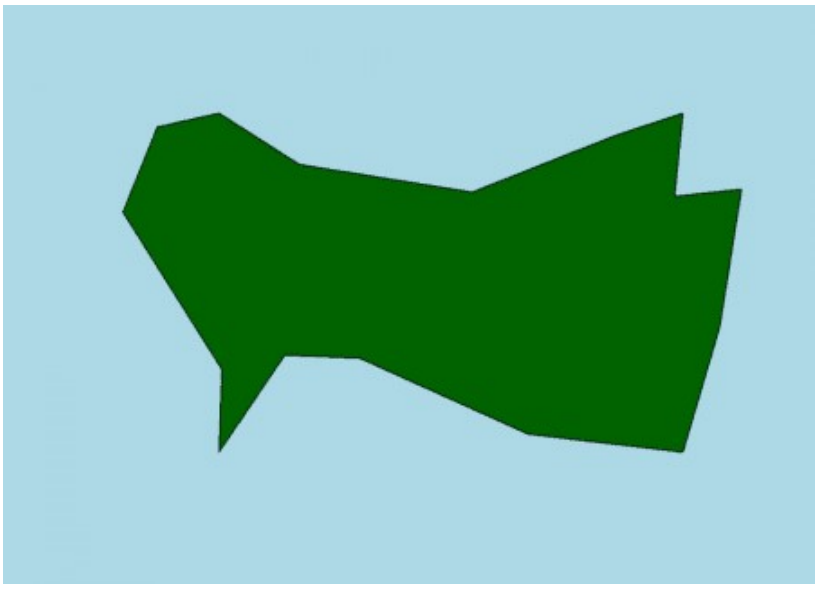
```
set.seed(2)
coord <- island(x, y)
plot_island(coord)
```



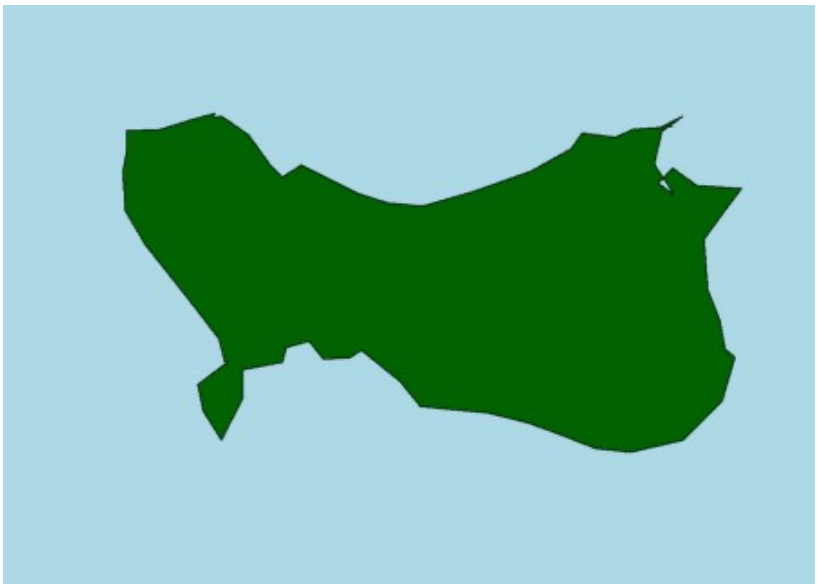
```
set.seed(2)
coord <- island(x, y, iter = 1)
plot_island(coord)
```



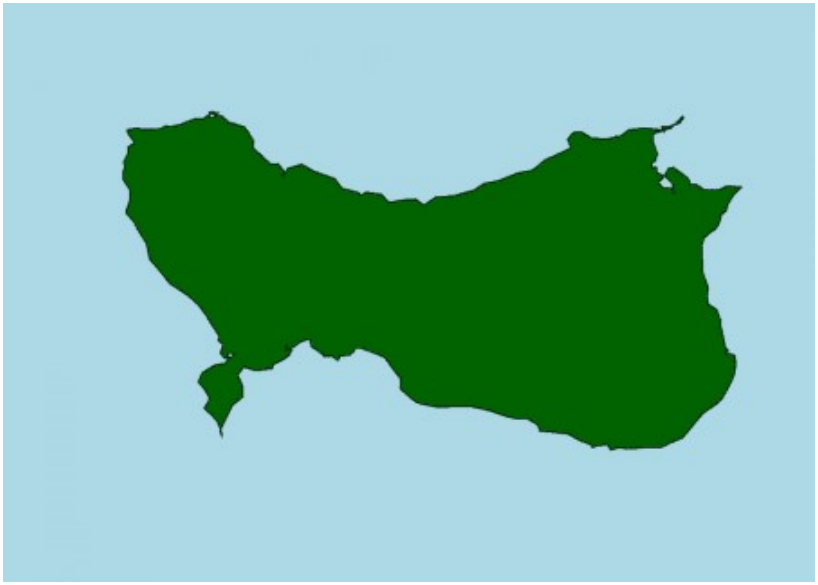
```
set.seed(2)
coord <- island(x, y, iter = 2)
plot_island(coord)
```



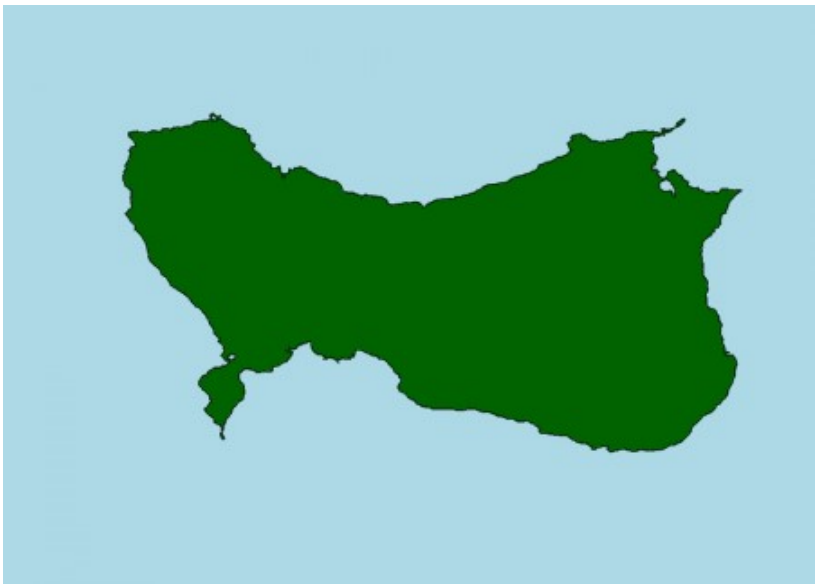
```
set.seed(2)
coord <- island(x, y, iter = 4)
plot_island(coord)
```



```
set.seed(2)
coord <- island(x, y, iter = 6)
plot_island(coord)
```



```
set.seed(2)
coord <- island(x, y, iter = 8)
plot_island(coord)
```



If you do your own experiments with the randomizer function and/or the seed and find an especially appealing example, please share it with us in the comments!

As a bonus, I would like to draw your attention to this little masterpiece of an educational film on fractals, created in the style of the great “Sin City” flick (~ 5 min.):

So, let me end this post with one last example of a volcanic island in a sea of lava… 😉

```
set.seed(5214)
coord <- island(x, y)
plot_island(coord, island_col = "black", water_col = "darkred")
```