A Guide to the TurtleGraphics Package for R

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http://www.gagolewski.com/software/TurtleGraphics/

Contents

1 The TurtleGraphics Package Introduction

The TurtleGraphics package offers R users the so-called "turtle graphics" facilities known from the Logo programming language. The key idea behind the package is to encourage children to learn programming and demonstrate that working with computers can be fun and creative.

The TurtleGraphics package allows to create either simple or more sophisticated graphics on the basis of lines. The Turtle, described by its location and orientation, moves with commands that are relative to its position. The line that it leaves behind can be controlled by disabling it or by setting its color and type.

The TurtleGraphics package offers functions to move forward or backward by a given distance and to turn the Turtle by a chosen angle. The graphical options of the plot, for example the color, type or visibility of the line, can also be easily changed.

We strongly encourage you to try it yourself. Enjoy and have fun!

2 Installation And Usage of The Package

2.1 Installation of the Package

To install the TurtleGraphics package use the following calls.

```
install.packages("TurtleGraphics")
```

Then you load the package by calling the library() function:

```
library("TurtleGraphics")
```

2.2 The Basics

2.2.1 Moving the Turtle

turtle_init. To start, call the turtle_init() function. It creates a plot region and places the Turtle in the Terrarium's center, facing north.

```
turtle_init()
```

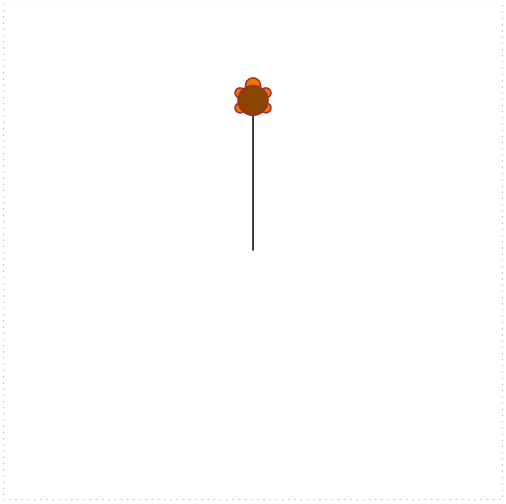
By default its size is 100 by 100 units. You can easily change it by passing appropriate values to the width and height arguments (e.g. turtle_init(width=200, height=200)).

To define what happens if the Turtle moves outside the plot region, you can set the mode option. The default value, "clip", means that the Turtle can freely go outside the board (but it will not be seen). The "error" option does not let the Turtle out of the Terrarium – if the Turtle tries to escape, an error is thrown. The third value, "cycle", makes the Turtle come out on the other side of the board if it tries to cross the border.

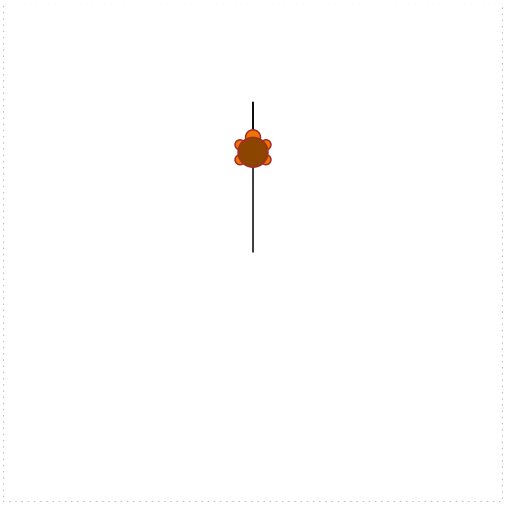
turtle_forward and turtle_backward. There are two main groups of functions that may be used to move the Turtle.

The first group consists in the turtle_forward() and the turtle_backward() functions. Their arguments define the distance you desire the Turtle to move. For example, to move the Turtle forward by a distance of 10 units, use the turtle_forward() function. To move the Turtle backwards you can use either the turtle_forward() function with a negative number as an argument, or simply use the turtle_backward() function.

```
turtle_init()
turtle_forward(dist=30)
```

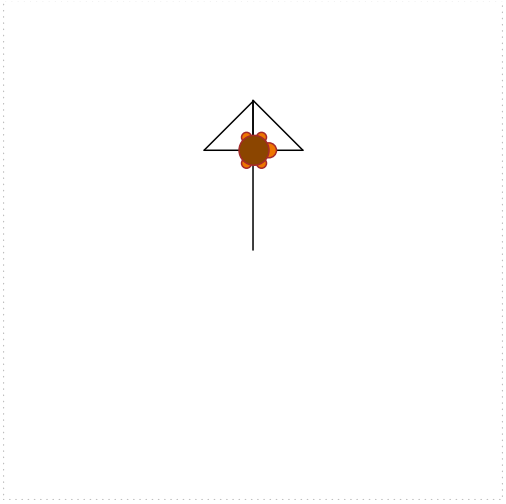


```
turtle_backward(dist=10)
```



turtle_right and turtle_left. The other group of functions deals with the Turtle's rotation. turtle_left and the turtle_right change the Turtle's direction by a given angle.

```
turtle_right(angle=90)
turtle_forward(dist=10)
turtle_left(angle=135)
turtle_forward(dist=14)
turtle_left(angle=90)
turtle_forward(dist=14)
turtle_left(angle=135)
turtle_forward(dist=10)
```

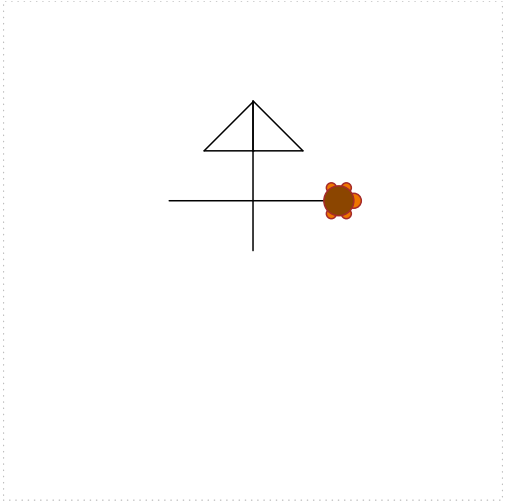


2.2.2 Additional Options

Let's discuss some additional features you can play with.

turtle_up and turtle_down. To disable the path from being drawn you can use the turtle_up() function. Let's consider a simple example. Turn the Turtle to the right by 90 degrees and then use the turtle_up() function. Now, when you move forward, the path is not visible. If you want the path to be drawn again you should call the turtle_down() function.

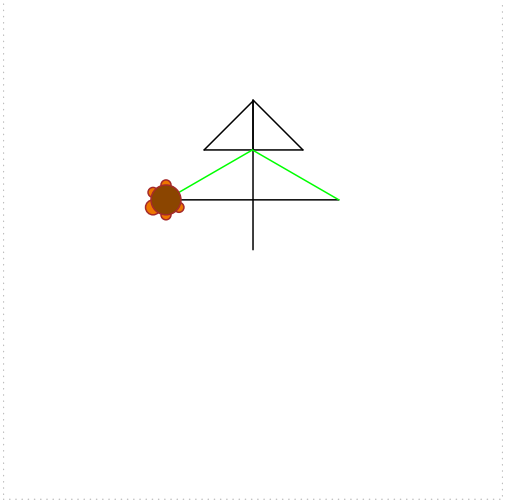
```
turtle_up()
turtle_right(90)
turtle_forward(dist=10)
turtle_right(angle=90)
turtle_forward(dist=17)
turtle_down()
turtle_left(angle=180)
turtle_forward(dist=34)
```



turtle_hide and turtle_show. Similarly, you may show or hide the Turtle's image, using the turtle_show() and turtle_hide() functions, respectively. If you are calling a bunch of functions at a time, it is strongly recommended to hide the Turtle first; it will speed up the drawing process, see also turtle_do().

turtle_col, turtle_lty and turtle_lwd. To change the style of the Turtle's trace, you can use the turtle_col(), turtle_lty(), and turtle_lwd() functions. The first one, as you can easily guess, changes the path color. For example, if you wish to change the trace to green, try:

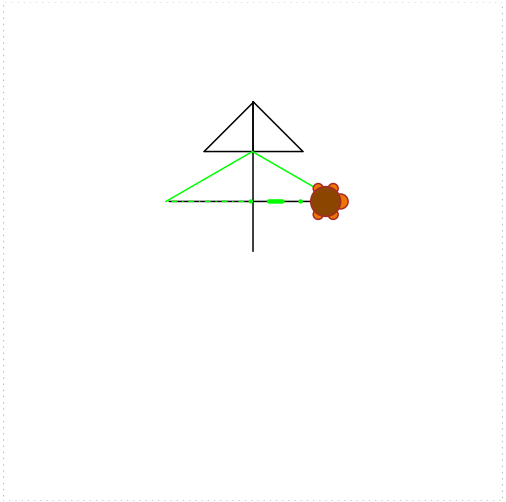
```
turtle_hide()
turtle_col(col="green")
turtle_left(angle=150)
turtle_forward(dist=20)
turtle_left(angle=60)
turtle_forward(dist=20)
turtle_show()
```



A comprehensive list of available colors is provided by the colors() function.

The turtle_lty() and turtle_lwd() functions change the style of the path. To change the "type" of the path, pass as an argument a number from 0 to 6 – each of these denotes a different type of the line (0 =blank, 1 =solid (default), 2 = dashed, 3 = dotted, 4 = dotdash, 5 = longdash, 6 = twodash). To change the width of the line, use the turtle_lwd() function.

```
turtle_left(angle=150)
turtle_lty(lty=4)
turtle_forward(dist=17)
turtle_lwd(lwd=3)
turtle_forward(dist=15)
```



turtle_status, turtle_getpos and turtle_getangle. If you got lost in the Terrarium (it's a jungle out there!), don't worry! Just use the turtle_status() function: it returns the current drawing settings. It provides you with the information on the width and height of the terrarium, whether the Turtle and its path are visible, where the Turtle is placed right now and at which angle, and so on.

```
turtle_init()
turtle_status()
```

```
## $DisplayOptions
## $DisplayOptions$col
## [1] "black"
##
## $DisplayOptions$lty
## [1] 1
##
## $DisplayOptions$lwd
## [1] 1
##
## $DisplayOptions$visible
## [1] TRUE
##
## $DisplayOptions$draw
## [1] TRUE
##
##
## $Terrarium
## $Terrarium$width
## [1] 100
##
## $Terrarium$height
## [1] 100
##
##
## $TurtleStatus
## $TurtleStatus$x
## [1] 50
##
## $TurtleStatus$y
## [1] 50
##
## $TurtleStatus$angle
## [1] 0
```

If you just want to know where the Turtle is, or what is its direction, try the turtle_getpos() and turtle_getangle() functions, respectively.

```
turtle_init()
turtle_getpos()
```

```
##  x  y
## 50 50
```

```
turtle_getangle()
```

```
## angle
##     0
```

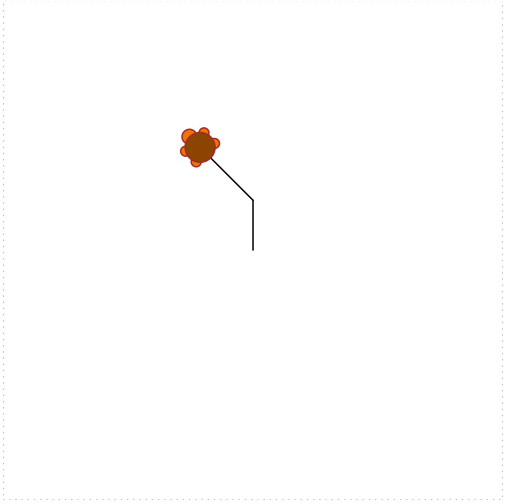
turtle_reset, turtle_goto, and turtle_setpos. If you wish to relocate the Turtle back to the starting position and reset all of the graphical parameters, call the turtle_reset() function.

The turtle_goto() and turtle_setpos() functions, on the other hand, asks the Turtle to go to the desired position. The latter never draws any path.

2.3 Advanced Usage of the Package

Now you are familiar with the basics. There are some more advanced ways to use the package. The (turtle_do()) function is here to wrap calls to multiple plot functions, because it temporarily hides the Turtle while the functions are executed. This results in more efficient plotting.

```
turtle_init()
turtle_do({
   turtle_move(10)
   turtle_turn(45)
   turtle_move(15)
})
```

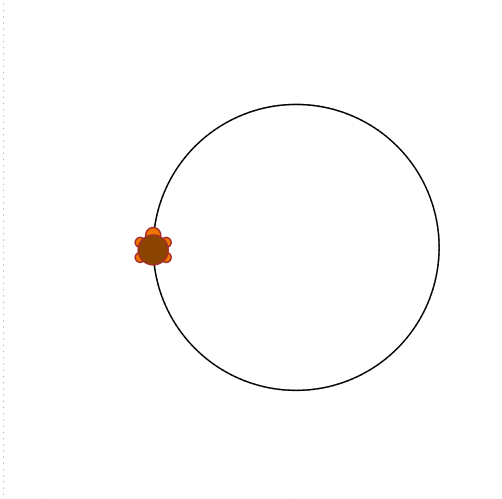


3 Introduction to R

3.1 The for loop.

This section illustrates how to connect the functions listed above with the options that R provides us with. For example, sometimes you would like to repeat some action several times. In such a case, we can use the for loop. The syntax is as follows: for (i in 1:100){ expr }. Such an expression will evaluate expr 100 times. For example:

```
turtle_init()
turtle_setpos(x=30, y=50)
turtle_do({
   for(i in 1:180) {
      turtle_forward(dist=1)
      turtle_right(angle=2)
   }
})
```

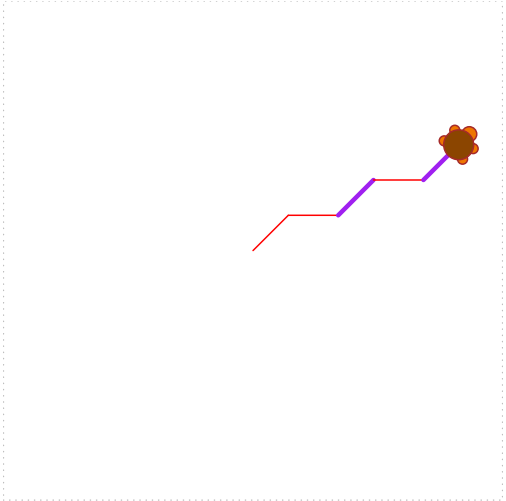


We strongly recommend to call each for loop always within turtle_do().

3.2 Conditional evaluation

There are some cases when you'd like to call a function provided that some condition is fulfilled. The if expression enables you to do so. The syntax is as follows: if (condition) { expr }. When the condition is fulfilled, the sequence of actions between the curly braces is executed. On the other hand, if (condition) { exprTRUE } else { exprFALSE } evaluates exprTRUE if and only if `condition` is met and exprFALSE otherwise. Let's study an example.

```
turtle_init()
turtle_do({
   for (i in 1:5) {
      x <- runif(1) # this function returns a random value between 0 and 1, see ?runif
      if (x>0.5) {
         turtle_right(angle=45)
         turtle_lwd(lwd=1)
         turtle_col(col="red")
      } else {
         turtle_left(angle=45)
         turtle_lwd(lwd=3)
         turtle_col(col="purple")
      }
      turtle_forward(dist=10)
   }
})
```



As you see, we make some random decisions here. If the condition is fulfilled, so the Turtle turns right and the path is drawn in red. Otherwise, we get a left turn and a purple path.

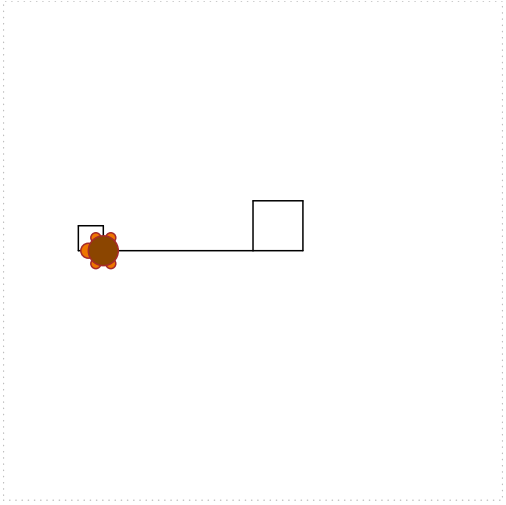
3.3 Functions

Sometimes it is desirable to "store" a sequence of expressions for further use. For example, if you'd like to draw many squares, you can write a custom function so that it can be called many times. For example:

```
turtle_square <- function(r) {
   for (i in 1:4) {
      turtle_forward(r)
      turtle_right(90)
   }
}
```

turtle_square is the name of the function. The parameters of the function are listed within the round brackets (separated by commas).

```
turtle_init()
turtle_square(10)
turtle_left(90)
turtle_forward(30)
turtle_square(5)
```



3.4 Recursion

The other thing you should know about is recursion. It is a process of repeating actions in a self-similar pattern.

Fractals make perfect examples of the power of recursion. Usually, a fractal is an image which at every scale exhibits the same (or very similar) structure. In Section 4 you have some typical examples of fractals – the fractal tree, the Koch snowflake and the Sierpiński triangle.

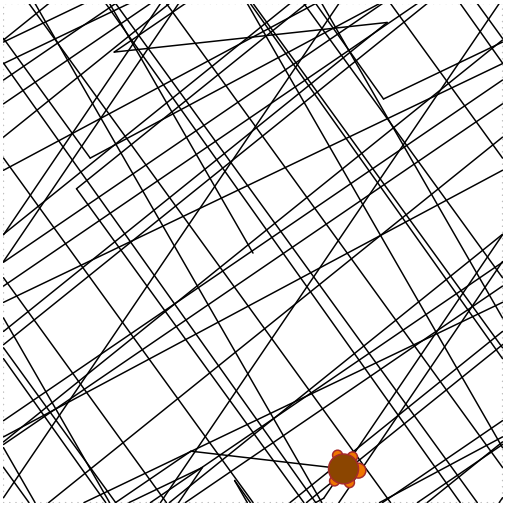
4 Examples

At the end of this guide we would like to present some colorful and inspiring examples.

4.1 Random lines

The first example generates random lines.

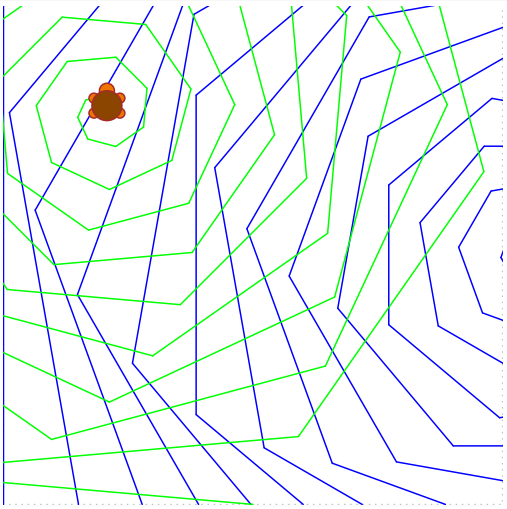
```
set.seed(124) # assure reproducibility
turtle_init(100, 100, mode = "cycle")
turtle_do({
   for (i in 1:10) {
      turtle_left(runif(1, 0, 360))
      turtle_forward(runif(1, 0, 1000))
   }
})
```



4.2 A spiral

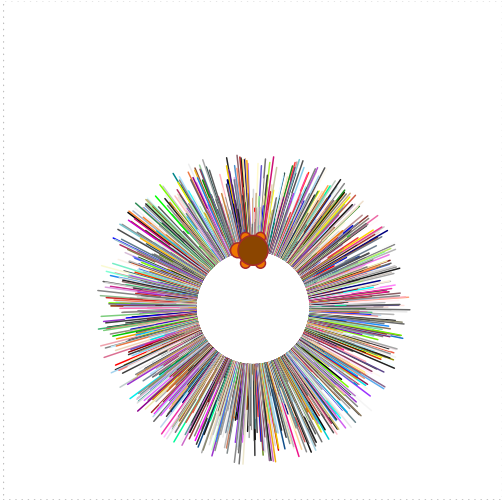
Let's draw some fancy spirals.

```
drawSpiral <- function(lineLen) {
   if (lineLen > 0) {
      turtle_forward(lineLen)
      turtle_right(50)
      drawSpiral(lineLen-5)
   }
   invisible(NULL) # return value: nothing interesting
}

turtle_init(500, 500, mode="clip")
turtle_do({
   turtle_setpos(x=0, y=0)
   turtle_col("blue")
   drawSpiral(500)
   turtle_setpos(x=250, y=0)
   turtle_left(45)
   turtle_col("green")
   drawSpiral(354)
   turtle_setangle(0)
})
```



4.3 A rainbow star

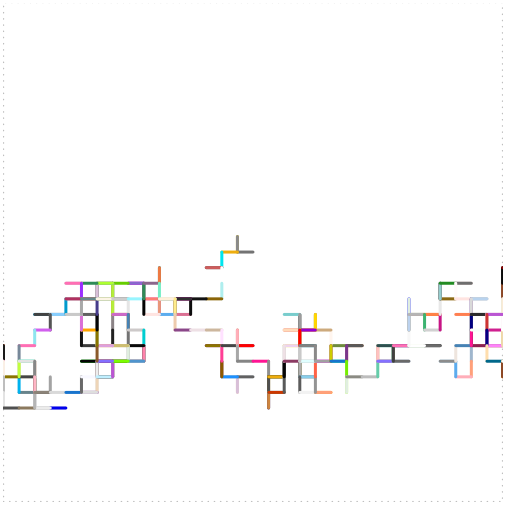
```
turtle_star <- function(intensity=1) {
   y <- sample(1:657, 360*intensity, replace=TRUE)
   for (i in 1:(360*intensity)) {
      turtle_right(90)
      turtle_col(colors()[y[i]])
      x <- sample(1:100,1)
      turtle_forward(x)
      turtle_up()
      turtle_backward(x)
      turtle_down()
      turtle_left(90)
      turtle_forward(1/intensity)
      turtle_left(1/intensity)
   }
}

set.seed(124)
turtle_init(500, 500)
turtle_do({
   turtle_left(90)
   turtle_star(5)
})
```



4.4 Brownian Turtle

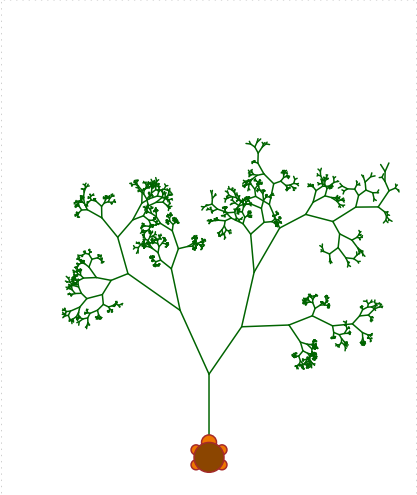
This example is inspired by the definition of a Brownian motion.

```
turtle_brownian <- function(steps=100, length=10) {
   turtle_lwd(2)
   angles <- sample(c(90,270,180,0), steps,replace=TRUE)
   coll <- sample(1:657, steps, replace=TRUE)
   for (i in 1:steps){
      turtle_left(angles[i])
      turtle_col(colors()[coll[i]])
      turtle_forward(length)
   }
}

set.seed(124)
turtle_init(800, 800, mode="clip")
turtle_do(turtle_brownian(1000, length=25))
```



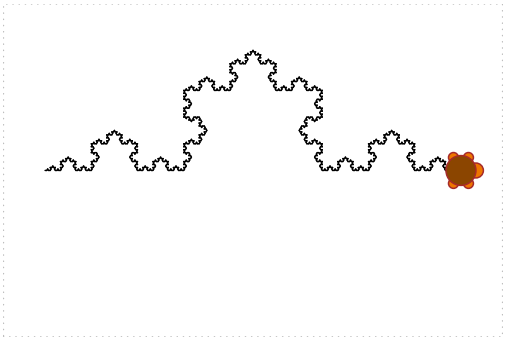
4.5 The Fractal Tree

```
fractal_tree <- function(s=100, n=2) {
   if (n <= 1) {
      turtle_forward(s)
      turtle_up()
      turtle_backward(s)
      turtle_down()
   }
   else {
      turtle_forward(s)

      a1 <- runif(1, 10, 60)
      turtle_left(a1)
      fractal_tree(s*runif(1, 0.25, 1), n-1)
      turtle_right(a1)

      a2 <- runif(1, 10, 60)
      turtle_right(a2)
      fractal_tree(s*runif(1, 0.25, 1), n-1)
      turtle_left(a2)

      turtle_up()
      turtle_backward(s)
      turtle_down()
   }
}

set.seed(123)
turtle_init(500, 600, "clip")
turtle_do({
   turtle_up()
   turtle_backward(250)
   turtle_down()
   turtle_col("darkgreen")
   fractal_tree(100, 12)
})
```



4.6 The Koch Snowflake

```
koch <- function(s=50, n=6) {
   if (n <= 1)
      turtle_forward(s)
   else {
      koch(s/3, n-1)
      turtle_left(60)
      koch(s/3, n-1)
      turtle_right(120)
      koch(s/3, n-1)
      turtle_left(60)
      koch(s/3, n-1)
   }
}


turtle_init(600, 400, "error")
turtle_do({
   turtle_up()
   turtle_left(90)
   turtle_forward(250)
   turtle_right(180)
   turtle_down()
   koch(500, 6)
})
```



4.7 The Sierpinski Triangle

```
drawTriangle <- function(points) {
   turtle_setpos(points[1,1], points[1,2])
   turtle_goto(points[2,1], points[2,2])
   turtle_goto(points[3,1], points[3,2])
   turtle_goto(points[1,1], points[1,2])
}

getMid <- function(p1, p2)
   (p1+p2)*0.5

sierpinski <- function(points, degree){
   drawTriangle(points)
   if (degree > 0) {
      p1 <- matrix(c(points[1,], getMid(points[1,], points[2,]),
                     getMid(points[1,], points[3,])), nrow=3, byrow=TRUE)

      sierpinski(p1, degree-1)
      p2 <- matrix(c(points[2,], getMid(points[1,], points[2,]),
                     getMid(points[2,], points[3,])), nrow=3, byrow=TRUE)

      sierpinski(p2, degree-1)
      p3 <- matrix(c(points[3,], getMid(points[3,], points[2,]),
                     getMid(points[1,], points[3,])), nrow=3, byrow=TRUE)
      sierpinski(p3, degree-1)
   }
   invisible(NULL)
}

turtle_init(520, 500, "clip")
turtle_do({
   p <- matrix(c(10, 10, 510, 10, 250, 448), nrow=3, byrow=TRUE)
   turtle_col("red")
   sierpinski(p, 6)
   turtle_setpos(250, 448)
})
```