CSEE W3827: Fundamentals of Computer Systems

Homework Assignment 3. Stephen Edwards. Columbia University

Due Tuesday, June 1, 2021 at 11:59 PM EDT via Courseworks

Download and edit the .s files in the hw3.zip file. Edit and make them work in the SPIM simulator `http://spimsimulator.sourceforge.net/` as discussed in class. Package your modified .s files in a **.zip file** and upload them to Courseworks to submit them. **Do not rename the .s files.** This time, you do not need to annotate or submit this file (hw3.pdf).

1. (25 pts.) In the SPIM simulator in MIPS assembly, write the *tri* routine in the `tri.s` skeleton to make it print a triangle. The height of the triangle will be given in $a0, and will be between 1 and 40 inclusive. For the first three tests, the included test harness should print

```
Testing itri with 1
*
Test complete

Testing itri with 2
 *
/*\
Test complete

Testing itri with 5
    *
   /*\
  //*\\
 ///*\\\
////*\\\\
Test complete
```

2. (30 pts.) In the SPIM simulator in MIPS assembly, implement the standard C function `strspn`:

   `size_t strspn(const char *s, const char *accept)`

   This returns the length (in bytes) of the initial segment of the string *s* that consists entirely of characters that appear somewhere in the zero-terminated *accept* string.

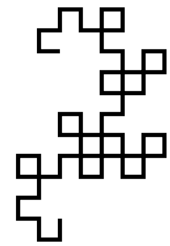
   Start from the `strspn.s` template.

   Your function must obey MIPS calling conventions.

   On the supplied test harness, your code should print

```
strspn("Hello World!", "Hloe") = 5
strspn("Hello World!", "H Wdelor") = 11
strspn("Hello World!", "!H Wdelor") = 12
strspn("Hello World!", "HHHHHHllllooo") = 1
strspn("Hello World!", "HHHHHHoooeeeelll") = 5
strspn("Hello World!", "HHHHHHoooeeeelll Wrld!") = 12
strspn("", "Hello World!") = 0
strspn("Hello World!", "") = 0
strspn("Hello World!", "Hello World!") = 12
strspn("Hello World!", "HelWrld!") = 4
strspn("", "") = 0
```

3. (45 pts.) Dragon curves are self-similar fractals that can be approximated recursively. Modify the *dragon.s* file by writing a recursive function called *dragon* that outputs a dragon curve of a given order in SVG format. Here's an order 6 dragon curve generated by my solution:

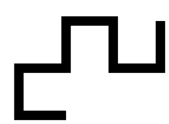


Below is pseudocode for the dragon curve algorithm written for "turtle graphics," in which the "turtle" has a current point and direction and can either move forward, drawing a line, or turn in place. Note that in the algorithm, *sign* is either 1 or -1, so the turtle only ever turns $90°$ or $-90°$.

procedure DRAGON(order, sign)
  if order $= 0$ **then**
    Move forward
  else
    DRAGON(order $- 1, 1$)
    Turn $90° \times$ sign
    DRAGON(order $- 1, -1$)

SVG is an XML-based text format for vector graphics. For this assigment, you only need to know that its paths can be expressed as a series of horizontal and vertical line segments. For example, `h-10` means "draw a horizontal segment 10 pixels to the left" and `v5` means "draw a vertical line segment 5 pixels down."

Here is the order 3 dragon, which consists of 8 line segments, and its corresponding SVG file:



```
<svg xmlns="http://www.w3.org/2000/svg">
<path stroke="black" fill="none"
      d="M225 225h-5v-5h5v-5h5v5h5v-5" />
</svg>
```

The provided skeleton includes a test harness that prints out everything but the various horizontal and vertical segments of the "d" attribute of the path. Don't change anything in the *main* function except for the order number.

Keep the current direction of the turtle, coded as a byte with values 0, 1, 2, and 3, in the global variable in memory *direction*. To move forward, print a string from the *dirs* array of string pointers, which contain strings encoding the four compass directions in SVG, indexed by *direction*. To turn, update the *direction* byte according to the *sign* argument (passed as a signed integer in register $a1).

Your solution needs to be recursive. You will have to store various registers (such as $ra) on the stack when your function is entered and restore them when you return. My solution was about 40 lines.

I debugged my code by writing the output of my program to a .svg file and previewed it with the Chrome browser. Inkscape can work, but the curves may appear outside the document area.