# Computing for Graphics
# C Programming Assignment Report

Quentin Corker-Marin
i7624405
Computer Visualisation and Animation, Level C
Faculty of Media and Communication
Bournemouth University

May 10, 2015

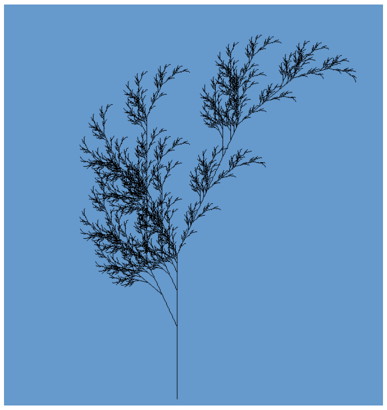


Figure 1: Example of a fractal plant drawn with my program

**Abstract**

This report outlines my approach to solving the task of implementing a turtle-graphics like program that would draw simple fractal shapes, going through sections of problem analysis, technical implementation and then a conclusion. I chose to use Lindnermayer Systems to create the instructions for the turtle to follow and the Simple DirectMedia Layer (SDL) graphics libraries for drawing to the screen and saving images.

## 1 Introduction

**The Task:** to implement a simple turtle in C/C++ and use this to create a fractal drawing program that is capable of the following:

1. Draw (at least) three different fractals that are selectable by the user (e.g. maple leaf, Sierpinski curve and Barnsley fern)
2. Allow the user to select/change the drawing parameters such as drawing and background colours, the recursion depth of the fractal etc.
3. Save the resulting fractals as image files, and optionally save the fractal drawing as an image sequence that either shows each level of the recursion as a separate frame or that shows each line segment at the target depth as a separate frame that would show the curve being drawn step by step

### 1.1 Turtle Graphics

Turtle Graphics is a method for generating vector graphics images [?] by implementing an imaginary turtle with a pen in its mouth. The Turtle has 3 main attributes:

1. position
2. heading
3. pen state (up/down, colour, line width etc.)

This turtle understands simple commands such as `PenUp()`, `PenDown()`, `Forward(distance)`, `Left(angle_increment)`, `Right(anlge_incriment)`. These commands can then be used to draw lines and be placed in iterative loops to create recursive patterns. Further reading on turtle graphics can be found at: `http://en.wikipedia.org/wiki/Turtle_graphics`.

### 1.2 Lindenmayer Systems

Lindenmayer systems are parallel rewriting systems and a type of formal grammar [?] that use replacement rules to expand characters strings. The starting string is known as the axiom. The character replacement is performed iteratively on the result of the previous replacement. They were originally developed as a way of modelling cell and plant growth [?]. An L-System is made up of three components:

1. An alphabet of all available characters that can be built up into strings.
2. An axiom (starting string made up of characters from the alphabet).
3. A set of rewriting rules that map characters from one string to another.

The most simple type of L-Systems are deterministic and context-free ( known as DOL-*systems*) in which each character in the alphabet has single production rule that maps it to other characters. This would be written as:

$\omega \ : \ A$

$A \ \rightarrow \ B$

$B \ \rightarrow \ AB$

Where $\omega$ is the axiom and $\rightarrow$ indicates a rule that maps the character on the left to the string on the right. When no rule is specified for a character it maps to its self. In this case the alphabet is not explicitly specified but is implied by the rule set which only involves the characters $A$ and $B$. After a single iteration, the string would be:

$B$

This would then become:

$AB$

Then:

$BAB$

$ABBAB$

$BABABBAB$

$\ldots$

L-Systems can be made more complicated by introducing parametric rules such as $A(x) \ \rightarrow \ A(2x)B(x)$ where $x$ could relate to the length of the line being drawn or some other parameter that would change the way it behaves. Context sensitive rules are another extension that could be added in which the characters to the left and right of the one being looked at can be taken into account. These would take the form $A < B < C \rightarrow D$ which means that $B$ would be replaced by $D$ if preceded by $A$ and followed by $D$. Further reading on Lindenmayer Systems can be found at: `http://en.wikipedia.org/wiki/L-system`.

# 2 The Program

## 2.1 Problem Analasys

To solve the given task I chose to write functions for creating strings using L-System axioms and rule sets and then implement a turtle that understood these commands and would draw them to the screen to be saved off. I wanted the turtle that I was going to implement to understand the following commands from the L-system:

- `F` : Move forward by distance d with the pen down.
- `A` : Move forward by distance d with the pen down.
- `B` : Move forward by distance d with the pen down.
- `f` : Move forward by distance d with the pen up.
- `X` : Does nothing but can be used for replacement rules
- `Y` : Does nothing but can be used for replacement rules
- `+` : Turn left by a angle $\theta$.
- `-` : Turn right by angle $\theta$.
- `[` : Store the current position and heading of the turtle in a stack.
- `]` : Pop the latest stored position from the top of the stack.

To do this I broke the problem down into these steps:

1. Take user input to decide what L-system was to be drawn, and other parameters such as colour, number of iterations etc.
2. Create the final string from the axiom and production rules.
3. Implementing a turtle that would understand the L-system strings.
4. Storing and popping off turtles from a sack.
5. Drawing the lines produced by the turtle.
6. Wrapping everything up in a GUI.
7. Being able to update the drawing screen to respond to clicks on buttons from the user.

Looking at this list I could tell that the harder problems to solve would be the implementation of a turtle stack, and linking everything with a GUI.

## 2.2 Implementation

Detailed descriptions of all structures and functions mentioned in this section can be found in the document `refman.pdf` which is also included as an appendix in this document.

### 2.2.1 L-Systems

The functions for creating L-system strings are defined in `lsys.c` and all of these work with the lsystem structure defined in `structures.c`. This structure holds space for an axiom, and all rules that the turtle understands as well as drawing flags, line colours and other variables that will be used later on in the drawing process. For a full description of the structure, please see `refman.pdf`.

The process of producing the final string (all brought together in the `makeString()` function) is:

1. Allocate memory to hold the axiom and set a pointer in the lsystem structure to point at this space.
2. Copy the axiom into this memory space.
3. Run character replacement iterations using the `iteration()` function (the number of iterations is held in another variable within the lsystem structure) this involves:
   (a) Running through the original string and, for each character, adding to a counter that will hold the total number of characters that will be in the new string.
   (b) Allocating the required amount of memory (which was just counted) for the new string and setting a temporary pointer to point to this space.
   (c) Running through the original string again, but this time, using the `strcat()` function to append the required replacement string to the temporary pointer.
   (d) The pointer in the lsystem structure that points to the old string is then freed and set to point at the new string while the temporary pointer is set to `NULL`.

### 2.2.2 Turtle

The functions for converting the output string held in the lsystem structure to lines to be drawn on the screen are defined in `turtle.c`. These work with a turtle that is updated as it goes through the string and when it moves with a pen down, the relevant pair of coordinates (that define the start and end points of a line to be drawn) are added to an array that can be passed to a drawing function. To store and pop positions for the turtle to use, a turtle stack is implemented in the form of a linked list. This is a list in which each element contains a pointer to the next element, as opposed to being held in an array of contiguous memory. The same turtle structure used for the drawing turtle is used for the stack. The use of a linked list greatly simplifies the addition and subtraction of turtles from the stack. The process of saving a turtle state is:

1. allocate memory for a new turtle.
2. copy current turtle data to the new memory.
3. set new turtle to point to the turtle currently at the top of the stack
4. set stack pointer to the new turtle which becomes the new top of the stack

The process for popping a turtle from the top of the stack is equally simple:

1. copy data from the top of the turtle stack to the current turtle
2. set a temporary pointer to point to the second turtle in the stack
3. free memory containing the top turtle
4. set stack pinter to point to the same location as the temp pointer and set the temp pointer to `NULL`

The SDL libraries define a line drawing algorithm however, as it was necessary to check the position being drawn at point by point so that the lines don't spill over into the GUI section of the window I adapted an implementation of the Bresenham line drawing algorithm [**?**]. This is an algorithm for drawing lines to a raster grid. It does this by keeping track of an error value which represents the distance from where the line exits a ixel to the top of that pixel [**?**]. The algorithm for this implementation is:

1. Take in a start and end point for the line $((x1, y1)$ and $(x2, y2))$.
2. Calculate the change in x and y across the line ($\Delta x = |x1 - x2|$ and $\Delta y = |y1 - y2|$)
3. To find which direction the line is being drawn in calculate the $x$ increment $sx$ using `sx = x0<xn ? 1 : -1;` and the $y$ increment $sy$ using `sy = y0<yn ? 1 : -1;`. This ensures that when x and y are changed as the function moves from pixel to pixel, it can move in any direction relative to the starting point (as opposed to a basic implementation which is limited to positive x and y increments only).
4. An initial error is calulated using `error = (dx>dy ? dx : -dy)/2;`. This is finding the driving axis along which the line moves (the driving axis is the direction in which the point will be incremented after every point drawn). This, combined with the x and y increments previously calculated decides which octant the line is being drawn in.
5. Set current point to $(x1,\ y1)$
6. While the current point is not the end point:
   (a) Draw at current point
   (b) Calculate new error value and increment the current point accordingly.

### 2.2.3 GUI

The functions that bring the lsystem and turtle functions together in a GUI are defined in `ui.c`. Each displayable window has an array of buttons associated with it which is passed to both the window drawing functions and mouse click handling functions. This makes it easier to add buttons to a screen and reformat them as I only need to change the details in the array and add to a counter that counts the total number of elements in an array. Each window also has its own drawing function and click handling function to allow for slightly different designs between windows and allow things to be displayed and clicked on that may not come under the conventional button structure.

The control flow for displaying things to the screen is as follows:

1. Button arrays for each window are defined and window flag is set to the home window.

2. The correct window is drawn (dependant on the window flag).
3. The window is refreshed until there is a click event.
4. The relevant click event handling function is run (again dependant on the window flag).
5. Flags are set and variables changed depending on where the click was on the screen.
6. Window is refreshed so that any window changes or parameter changes are now shown on the screen.

## 3 Conclusions

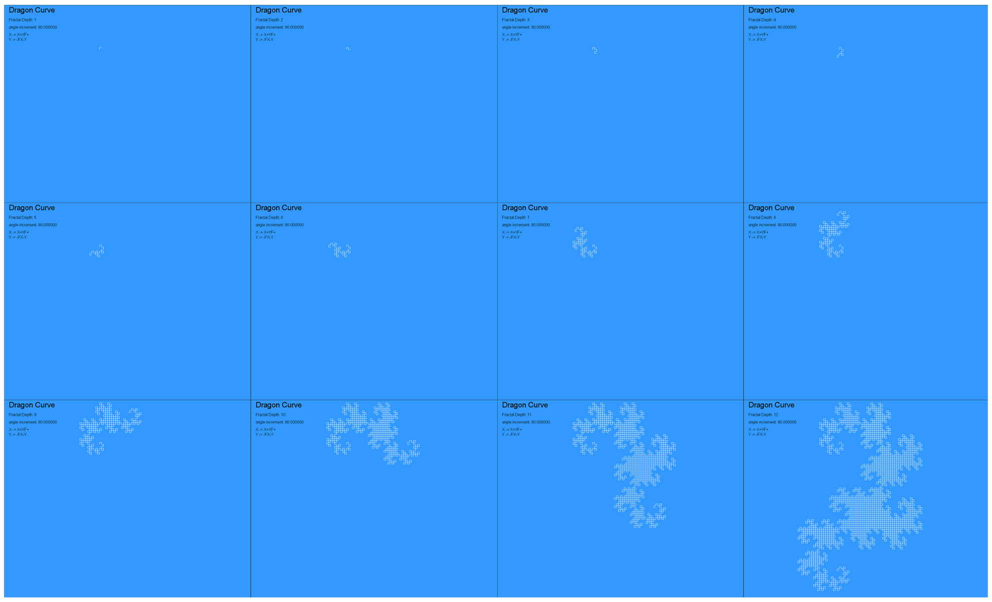
I believe the implementation to be a success as the final program is able to do everything that was outlined in the brief as it can draw 8 different fractal patterns, in different colours and with different drawing parameters and save the results as images and image sequences to be converted into videos.

However, it would have been nice to allow the user to define their own rule sets to create their own L-systems. This was originally part of the design and fully implemented before everything was linked in the GUI but was cut when that was introduced as it was proving to be very complicated to display live text fields on the renderer and I didn't want to revert to the command line input as it would detract from the user experience. Because of the way that the L-systems are implemented, once text fields were introduced it would not be too much hassle to link then to the turtle section and then to the drawing screen.

There can also be problems with artefacts appearing on the saved sequences if the window is moved while they are being saved. To try and solve this problem I hid the window while the sequence was being saved but this resulted in blank sequences. I was not sure how to fix this in the end but by printing a warning message to the user I can hope that they don't move the window. However, this is a less than satisfactory solution.

If I were to do the project over I would spend more time on making the GUI neater and allowing the user to input their own L-system rule sets. I would also attempt to write it in C++ as opposed to C as the object oriented features would help simplify and neaten un the GUI.

There now follows a few example images that were saved out using the save functions in the program:



```
Dragon Curve
Fractal Depth: 1
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 2
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 3
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 4
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 5
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 6
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 7
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 8
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

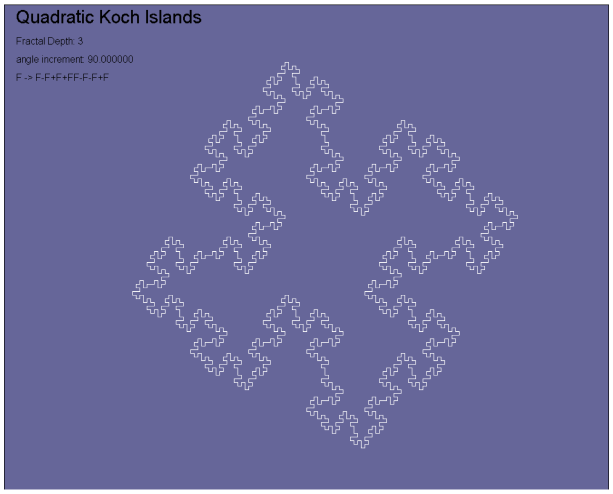
```
Dragon Curve
Fractal Depth: 9
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 10
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 11
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

```
Dragon Curve
Fractal Depth: 12
angle increment: 90.000000
X -> X+YF+
Y -> -FX-Y
```

Figure 2: Successive iterations of a dragon curve



```
Quadratic Koch Islands
Fractal Depth: 3
angle increment: 90.000000
F -> F-F+F+FF-F-F+F
```

Figure 3: Quadratic Koch Curve, fractal depth: 3

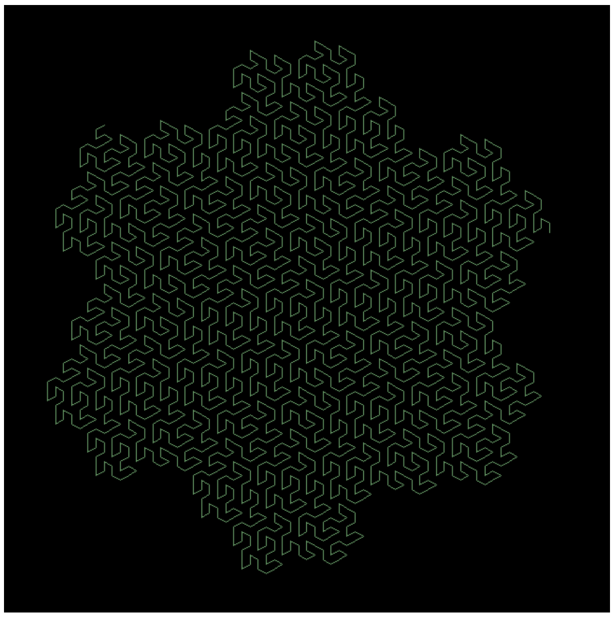


Figure 4: Gosper Curve, fractal depth: 4

## References

[1] Anderson, E. F., 2015. *CFG Lecture Slides, week 19* [online]. NCCA. Available from: `https://mybu.bournemouth.ac.uk/bbcswebdav/pid-1132052-dt-content-rid-2480584_2/courses/061019/CFGlecture19print.pdf` [accessed on 10/5/2015].

[2] Joy, K. I., 2009. *On-Line Computer Graphics Notes, Bresenham Algorithm* Department of Computer Science, University of California. Available from: `http://www.idav.ucdavis.edu/education/GraphicsNotes/Bresenhams-Algorithm.pdf` [accessed on 10/5/2015].

[3] Parlante, N., 1998. *Linked List Basics* [online]. Stanford CS Education Library Available from: `http://cslibrary.stanford.edu/103/LinkedListBasics.pdf` [accessed on 10/5/2015].

[4] Wikipedia, 2015. *Turtle Graphics* [online]. Available from: `http://en.wikipedia.org/wiki/Turtle_graphics` [Accessed on 10/5/2015].

[5] Wikipedia, 2015. *L-system* [online]. Available from: `http://en.wikipedia.org/wiki/L-system` [Accessed on 10/15/2015].

## 4 Appendix

# Contents

**1 Data Structure Index** **1**

1.1 Data Structures . . . . . 1

**2 File Index** **3**

2.1 File List . . . . . 3

**3 Data Structure Documentation** **5**

3.1 btn Struct Reference . . . . . 5

3.1.1 Detailed Description . . . . . 5

3.2 coordinate Struct Reference . . . . . 5

3.2.1 Detailed Description . . . . . 6

3.3 line Struct Reference . . . . . 6

3.3.1 Detailed Description . . . . . 6

3.4 lsystem Struct Reference . . . . . 6

3.4.1 Detailed Description . . . . . 7

3.5 turtle_state Struct Reference . . . . . 7

3.5.1 Detailed Description . . . . . 8

**4 File Documentation** **9**

4.1 src/lsys.c File Reference . . . . . 9

4.1.1 Detailed Description . . . . . 10

4.1.2 Function Documentation . . . . . 10

4.1.2.1 iteration . . . . . 10

4.1.2.2 makeString . . . . . 10

4.1.2.3 initLsystem . . . . . 10

4.1.2.4 dtor . . . . . 10

4.1.2.5 rtod . . . . . 11

4.1.2.6 resetString . . . . . 12

4.1.2.7 resetLines . . . . . 12

4.1.2.8 sierpinski . . . . . 12

4.1.2.9 dragon . . . . . 12

4.1.2.10 plant1 . . . . . 12

4.1.2.11 plant2 . . . . . 12
4.1.2.12 islands . . . . . 13
4.1.2.13 snowflake . . . . . 13
4.1.2.14 quadKoch . . . . . 13
4.1.2.15 gosper . . . . . 13
4.2 src/main.c File Reference . . . . . 13
4.2.1 Detailed Description . . . . . 14
4.2.2 Function Documentation . . . . . 14
4.2.2.1 init . . . . . 14
4.2.2.2 main . . . . . 14
4.3 src/structs.c File Reference . . . . . 14
4.3.1 Detailed Description . . . . . 15
4.3.2 Function Documentation . . . . . 15
4.3.2.1 structInitLsystem . . . . . 15
4.3.2.2 structInitCoord . . . . . 15
4.3.2.3 structInitLine . . . . . 15
4.3.2.4 structInitBtn . . . . . 15
4.3.2.5 structInitTurtleState . . . . . 15
4.4 src/turtle.c File Reference . . . . . 16
4.4.1 Detailed Description . . . . . 16
4.4.2 Function Documentation . . . . . 16
4.4.2.1 stringToTurtle . . . . . 16
4.4.2.2 savePos . . . . . 17
4.4.2.3 popPos . . . . . 17
4.4.2.4 penDownLine . . . . . 17
4.4.2.5 penUpLine . . . . . 17
4.4.2.6 countMoves . . . . . 18
4.5 src/ui.c File Reference . . . . . 18
4.5.1 Detailed Description . . . . . 19
4.5.2 Function Documentation . . . . . 19
4.5.2.1 createHomeScreenButtons . . . . . 19
4.5.2.2 createOptionsScreenButtons . . . . . 19
4.5.2.3 createDrawScreenButtons . . . . . 19
4.5.2.4 drawHomeScreen . . . . . 21
4.5.2.5 drawOptionsScreen . . . . . 21
4.5.2.6 drawDrawingScreen . . . . . 21
4.5.2.7 homeScreenClick . . . . . 22
4.5.2.8 optionsScreenClick . . . . . 22
4.5.2.9 drawScreenClick . . . . . 22
4.5.2.10 createHomeButton . . . . . 23

4.5.2.11 createBackButton . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 23
4.5.2.12 addButton . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 23
4.5.2.13 drawTextToRenderer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 24
4.5.2.14 drawButtonToRenderer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 24
4.5.2.15 drawAllButtonsToRenderer . . . . . . . . . . . . . . . . . . . . . . . . . . . 24
4.5.2.16 drawColourChartToRenderer . . . . . . . . . . . . . . . . . . . . . . . . . . 24
4.5.2.17 drawInputColourBox . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 25
4.5.2.18 drawInfoToRenderer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 25
4.5.2.19 drawLine . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 25
4.5.2.20 drawFractal . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 26
4.5.2.21 printRule . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 26
4.5.2.22 clickInButton . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 26
4.5.2.23 getPixelColour . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 26
4.5.2.24 drawBG . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 28
4.5.2.25 imgSave . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 28
4.5.2.26 sequenceSave . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 28

**Index** **29**

# Chapter 1

# Data Structure Index

## 1.1 Data Structures

Here are the data structures with brief descriptions:

btn . . . . . . . . . . 5
coordinate . . . . . . . . . . 5
line . . . . . . . . . . 6
lsystem . . . . . . . . . . 6
turtle_state . . . . . . . . . . 7

# Chapter 2

# File Index

## 2.1 File List

Here is a list of all documented files with brief descriptions:

src/lsys.c
A source file for functions used in the creation of lsystem strings . . . . . . . . . . . . . . . . . 9
src/**lsys.h** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **??**
src/main.c
A source file for the main finction that will run the program . . . . . . . . . . . . . . . . . . . . . 13
src/structs.c
A source file for functions used ito intitialise structures requied for the program . . . . . . . . . 14
src/**structs.h** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **??**
src/turtle.c
A source file for functions used to convert lsystem strings into arrays of coordinate pairs that make up the lines to be drawn . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 16
src/**turtle.h** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **??**
src/ui.c
File containing source code for all UI functions . . . . . . . . . . . . . . . . . . . . . . . . . . . 18
src/**ui.h** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **??**

# Chapter 3

# Data Structure Documentation

## 3.1 btn Struct Reference

```
#include <structs.h>
```

### Data Fields

- coordinate tl_corner

  *Coordinate of the top left corner of the box.*
- int width

  *Width of the button.*
- int height

  *Height of the button.*
- TTF_Font $*$ font

  *A font to be used for the text lable on the button.*
- char text [40]

  *A characer string to hold the buttons lable.*
- SDL_Colour colour

  *The colour of the button.*

### 3.1.1 Detailed Description

A structure for holding all the information required for creating a button on the screen.

The documentation for this struct was generated from the following file:

- src/structs.h

## 3.2 coordinate Struct Reference

```
#include <structs.h>
```

### Data Fields

- double x_pos

  *x positon of the coordinate pair.*
- double y_pos

  *y position of the coordinate pair.*

### 3.2.1 Detailed Description

A coordinate structure to hold an (x, y) coordinate pair.

The documentation for this struct was generated from the following file:

- src/structs.h

## 3.3 line Struct Reference

```
#include <structs.h>
```

### Data Fields

- coordinate start

  *Coordinate sructure for the start of the line.*
- coordinate end

  *Coordinate structure for the end of the line.*

### 3.3.1 Detailed Description

A line structure that holds a coordinate pair that defines a line between two points

The documentation for this struct was generated from the following file:

- src/structs.h

## 3.4 lsystem Struct Reference

```
#include <structs.h>
```

### Data Fields

- char name [40]

  *A character string for the name of the L-System.*
- char axiom [40]

  *A haracter array for the starting string (axiom) of the L-System.*
- SDL_Colour bg_colour

  *Background colour for the drawing screen.*
- SDL_Colour ln_colour

  *Line colour for the drawing screen.*
- coordinate start

  *Starting point for the turtle drawing the L-System.*
- double angle

  *Angle for the turtle to turn through each time the angle is increased or decreaseed.*
- int length

  *Length of each individual line to be drawn.*
- int iterations

  *Fractal depth of the L-System (how many times the character replacement is performed).*
- int iteration_limit

  *A maximum fractal depth which can be different for different L-Systems so that the program is not drawing too much and stays fast.*
- int img_file_num

  *A counter that counts how many images have been saved so that conflicting names are not produced in a single run of the program.*
- int seq_file_num

  *A counter that counts how many images have been saved to a sequence so that conflicting names are not produced in a single run of the program.*
- char ∗ string

  *A pointer to the L-System string to be drawn.*
- line ∗ line_list

  *A opinter to an array of lines that are calculated using the string.*
- int line_list_length

  *A counter that recrds the length of the line list.*
- int remake_lines_flag

  *A flag which tells the program to recalculate the line list.*
- int remake_string_flag

  *A flag which tells the program to recalculate the string.*
- int info_disp_flag

  *A flag which tells the program to display the L-System info to the screen.*
- char rule_A [40]

  *character replacement string for the 'A' chracter.*
- char rule_B [40]

  *character replacement string for the 'B' chracter.*
- char rule_F [40]

  *character replacement string for the 'F' chracter.*
- char rule_f [40]

  *character replacement string for the 'f' chracter.*
- char rule_X [40]

  *character replacement string for the 'X' chracter.*
- char rule_Y [40]

  *character replacement string for the 'Y' chracter.*
- char rule_plus [40]

  *character replacement string for the '+' chracter.*
- char rule_minus [40]

  *character replacement string for the '-' chracter.*
- char rule_store [40]

  *character replacement string for the '[' chracter.*
- char rule_pop [40]

  *character replacement string for the ']' chracter.*

### 3.4.1 Detailed Description

A structure that holds all of the information required for the creation and drawing of an lsystem

The documentation for this struct was generated from the following file:

- src/structs.h

## 3.5 turtle_state Struct Reference

```
#include <structs.h>
```

### Data Fields

- coordinate pos

  *Current position of the turtle.*
- double heading

  *Heading of the turtle (stored as radians).*
- struct turtle_state ∗ next

  *Pointer to the next element in a linked list.*

### 3.5.1 Detailed Description

A structure that stores information on a turtle, including a pointer to the next turtle for the creation of a linked list that will be used to create a turtle stack.

The documentation for this struct was generated from the following file:

- src/structs.h

# Chapter 4

# File Documentation

## 4.1 src/lsys.c File Reference

A source file for functions used in the creation of lsystem strings.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "structs.h"
#include "lsys.h"
```

### Macros

- #define M_PI 3.14156265359

    *A macro definition for the mathematical constant Pi.*

### Functions

- void iteration (lsystem ∗lsys)
- int makeString (lsystem ∗lsys)
- void initLsystem (lsystem ∗lsys)
- double dtor (double degrees)
- double rtod (double radians)
- void resetString (lsystem ∗lsys)
- void resetLines (lsystem ∗lsys)
- void sierpinski (lsystem ∗lsys)
- void dragon (lsystem ∗lsys)
- void plant1 (lsystem ∗lsys)
- void plant2 (lsystem ∗lsys)
- void islands (lsystem ∗lsys)
- void snowflake (lsystem ∗lsys)
- void quadKoch (lsystem ∗lsys)
- void gosper (lsystem ∗lsys)

### 4.1.1 Detailed Description

A source file for functions used in the creation of lsystem strings.

The L-System string is created by performing a character replacement on a starting string (axiom) using a set of character replacement rules and then recursivly calling the same character replacement reules on the result of the previous string to the required depth of iterations.

### 4.1.2 Function Documentation

#### 4.1.2.1 void iteration ( **lsystem** ∗ *lsys* )

Performes a single iteration of character replacement for a string.

This is done by firstly counting up the new length of the string, then allocating the required amout of memory before finaly creating the new string, freeing the old one, thensetting the poonter to point at the newly created string.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | the lsystem that holds the rules for character replacement and the string |

#### 4.1.2.2 int makeString ( **lsystem** ∗ *lsys* )

takes in the axiom and the rules and produces the final string, using the number of iterations specified by the user.

Firstly, memory is allocated for the axiom to be places in the string container, this allocation is then checked before the iteration() function is then run on the string for the required number of iterations.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | a pointer to the lsystem that contaisn the rules, axiom, old string, and number of iterations. |

**Returns**

returns 1 if sucessfull, and 0 if memory allocation failed.

#### 4.1.2.3 void initLsystem ( **lsystem** ∗ *lsys* )

Sets all rules in an lsystem to map to them selves so that there will be a default rule for each character in the string. Also intiialises other values that will be the default values for creation/drawing ect.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | an lsystem that will store the information. |

#### 4.1.2.4 double dtor ( double *degrees* )

converts an angle from degrees into radians.

[in] degrees angle to be converted into radians.

**Returns**

angle in radians.

#### 4.1.2.5 double rtod ( double *radians* )

Converts an angle from radians into degrees.

**Parameters**

| | | |
|---|---|---|
| `in` | *radians* | angle to be converted into degrees. |

**Returns**

angle in dgrees

#### 4.1.2.6 void resetString ( lsystem ∗ *lsys* )

Frees the pointers string and resets the flag.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | lsystem that holds the data to be freed. |

#### 4.1.2.7 void resetLines ( lsystem ∗ *lsys* )

Frees the line list and resets the flag.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | lsystem that holds data to be freed |

#### 4.1.2.8 void sierpinski ( lsystem ∗ *lsys* )

Copy Sierpinski Triangle rules to the lsystem.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | lsystem for the rules to be copied to |

#### 4.1.2.9 void dragon ( lsystem ∗ *lsys* )

Copy Dragon Curve rules to the lsystem.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | lsystem for the rules to be copied to |

#### 4.1.2.10 void plant1 ( lsystem ∗ *lsys* )

Copy Fractal Plant 1 rules to the lsystem.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | lsystem for the rules to be copied to |

#### 4.1.2.11 void plant2 ( lsystem ∗ *lsys* )

Copy the rules for a fractal plant to the lsystem.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | system for the rules to be copied to. |

#### 4.1.2.12 void islands ( lsystem ∗ *lsys* )

Copy island and lake rules to the lsystem.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | lsystem for the rules to be copied to. |

#### 4.1.2.13 void snowflake ( lsystem ∗ *lsys* )

Copy Koch Snowflake rules to the lsystem.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | lsystem for the rules to be copied to |

#### 4.1.2.14 void quadKoch ( lsystem ∗ *lsys* )

Copy lsystem rules for a quadratic koch curve to the lsystem.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | lsystem for the rules to be copied too. |

#### 4.1.2.15 void gosper ( lsystem ∗ *lsys* )

Copy lsystem rules for a gosper curve to the lsystem.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | lsystem for the rules to be copied to. |

## 4.2 src/main.c File Reference

A source file for the main finction that will run the program.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "structs.h"
#include "lsys.h"
#include "ui.h"
```

### Functions

- int init ()
- int main ()

### 4.2.1 Detailed Description

A source file for the main finction that will run the program.

Firslty all SDL initilaisation functions are run and checked for sucess. Then variables for the L-System and rendereing functions are initilaised before being passed to the relevant functions for default values to be set up.

Once all variables have been declared and initilaised, a while loop that checks for events and handles window drawing operations for different click events is entered and only exited when the program is quit.

When the program is quit, all variables that need freeing/destroying are handlend and the program exits.

### 4.2.2 Function Documentation

#### 4.2.2.1 int init ( )

Initilaising SDL elements and printing errors if initialisation failed.

**Returns**

: true if errors occured during initilaisation.

#### 4.2.2.2 int main ( )

Intialisinf variables for, and controling the running of the program.

Initialises all varaibles with default values and defines the button sets for each window before frawing the rewuired window defined by the win_flag. Runs functions for handeling click events for changing the win_flag and parameters within the L-System.

**Returns**

0 if the program runs sucessfully.

## 4.3 src/structs.c File Reference

A source file for functions used ito intitialise structures requied for the program.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "structs.h"
```

### Functions

- void structInitLsystem (lsystem ∗lsys)
- void structInitCoord (coordinate ∗coord)
- void structInitLine (line ∗ln)
- void structInitBtn (btn ∗ui_button)
- void structInitTurtleState (turtle_state ∗turtle)

### 4.3.1 Detailed Description

A source file for functions used ito intitialise structures requied for the program.

Initialisation functions are required to insure defined behavior for every element in each structure.

### 4.3.2 Function Documentation

#### 4.3.2.1 void structInitLsystem ( **lsystem** ∗ *lsys* )

Initilaises an lsystem structure.

For use when declaring an lsystem to ensure that all elements have defined values and therfor predictable behavior.

**Parameters**

| | | |
|---|---|---|
| `out` | *lsys* | The lsystem structure to be initialized. |

#### 4.3.2.2 void structInitCoord ( **coordinate** ∗ *coord* )

Initilaises a coordinate structure.

For use when declaring a coordinate to ensure that all elements have defined values and therfor predictable behavior.

**Parameters**

| | | |
|---|---|---|
| `out` | *coord* | The coordinate structue to be initialised. |

#### 4.3.2.3 void structInitLine ( **line** ∗ *ln* )

Nnitilaises a line structure.

For use when declaring a line to ensure that all elements hae defined values and predictable behavior.

**Parameters**

| | | |
|---|---|---|
| `out` | *ln* | The line structure to be initialized. |

#### 4.3.2.4 void structInitBtn ( **btn** ∗ *ui_button* )

Initilaises a button structure

For use when declaring a button to ensure that all elements have defined values and predictable behavior.

**Parameters**

| | | |
|---|---|---|
| `out` | *ui_button* | The button structure to be initialized. |

#### 4.3.2.5 void structInitTurtleState ( **turtle_state** ∗ *turtle* )

Initilaises a turtle_state structure

For use when declaring a turtle_state structure to ensure that all elements have defined values and predictable behavior.

**Parameters**

| | | |
|---|---|---|
| `out` | *turtle* | The turtle structure to be initialized. |

## 4.4 src/turtle.c File Reference

A source file for functions used to convert lsystem strings into arrays of coordinate pairs that make up the lines to be drawn.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "structs.h"
#include "turtle.h"
#include "lsys.h"
```

### Functions

- int stringToTurtle (lsystem ∗lsys)
- void savePos (turtle_state ∗∗root, turtle_state current_turtle)
- void popPos (turtle_state ∗∗root, turtle_state ∗current_turtle)
- int penDownLine (turtle_state ∗current_turtle, int length, int line_list_pos, lsystem ∗lsys)
- void penUpLine (turtle_state ∗current_turtle, int length)
- int countMoves (char ∗string)

### 4.4.1 Detailed Description

A source file for functions used to convert lsystem strings into arrays of coordinate pairs that make up the lines to be drawn.

The sting is counted for characters which will produce a visible line and allocate memory for an array of lines of the required length, and then the program will run through the string again, updating the turtle as it goes and and add a pair of coordinates to the line list every time a line drawing character is encountered.

### 4.4.2 Function Documentation

#### 4.4.2.1 int stringToTurtle ( **lsystem** ∗ *lsys* )

The main function for converting the string produced by an lsystem into a list of coordinate pairs for lines to be drawn between.

This is done by firstly runnung through the string that defines the pattern to be drawn and counting the number of lines that will need to be drawn. This length is then used to allocate Memory for an array of lines. A turtle is then introduced and the string is gone through again. The turtle is kept updated and everytime it draws a line, one is added to the line list and if the position needs to be stored or retrieved from the turtle stack then it extracts or adds to the top element of the linked list.

**Parameters**

| | | |
|---|---|---|
| out | *lsys* | pointer to the lsystem (needed for angle incriment and line length). |

**Returns**

the number of coordinate pairs that are held in the line_list.

#### 4.4.2.2 void savePos ( turtle_state ** *root,* turtle_state *current_turtle* )

Saves the current position of the turtle to the top of the linked list.

This is done by initialising a new turtle state and filling it with the current_turtle data. This is then set to point to the top of the turtle stack and the previous pointer to the top is then set to point to the new top.

**Parameters**

| | | |
|---|---|---|
| out | *root* | ponter pointer to the root of the chain of positions. |
| in | *current_turtle* | the currentky active turtle. |

#### 4.4.2.3 void popPos ( turtle_state ** *root,* turtle_state * *current_turtle* )

pops off the top of the chain of saved turtle states, changing where the root points and freeing the removed data.

This is done by copying the data from the top of the turtle stack to the current_turtle, then setting a temporary pointet to point to the second element in the stack. The top of the stack is then freed and the pointer that wa pointing to the top is now set to the temporary pointer.

**Parameters**

| | | |
|---|---|---|
| out | *root* | pointer pointer to the top of the turtle stack. |
| out | *current_turtle* | pointer to the currently active turtle. |

#### 4.4.2.4 int penDownLine ( turtle_state * *current_turtle,* int *length,* int *line_list_pos,* lsystem * *lsys* )

Adds a line to the line list and updates the turtles position.

This function uses some simple trigonometry to calculate the final position of the turtle after drawing a line of a given length, from a given starting point at a given heading. The starting position and end position are then added to the line list as a pair of coordinates.

**Parameters**

| | | |
|---|---|---|
| out | *current_turtle* | pointer to the currently active turtle. |
| out | *line_list* | pointer pointer to the array of coordinate pairs for drawing lines. |
| in | *length* | length of each line to be drawn |
| in | *linelist_pos* | an integer that holds the current position of the next empty element in the line list. |

**Returns**

the current position in the line list.

#### 4.4.2.5 void penUpLine ( turtle_state * *current_turtle,* int *length* )

Moves the turtle by the line length using the current heading, but without adding that line to the line list.

This is done using simple trigonometry to calculate the change in x and y using the given length anf heading. These values are then added to the starting position and then the turtle is updated to this new position.

**Parameters**

| | | |
|---|---|---|
| out | *current_turtle* | pointer to the current active turtle. |
| in | *length* | length of the distance to be moved. |

### 4.4.2.6 int countMoves ( char ∗ *string* )

Runs through the string and counts the number of line drawing characters.

**Parameters**

| | | |
|---|---|---|
| in | *string* | string that is going to be run through and counted. |

## 4.5 src/ui.c File Reference

File containing source code for all UI functions.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "structs.h"
#include "lsys.h"
#include "turtle.h"
#include "ui.h"
```

### Functions

- void createHomeScreenButtons (btn ∗screen_buttons, TTF_Font ∗font)
- void createOptionsScreenButtons (btn ∗screen_buttons, TTF_Font ∗font)
- void createDrawScreenButtons (btn ∗screen_buttons, TTF_Font ∗title_font, TTF_Font ∗body_font)
- void drawHomeScreen (SDL_Renderer ∗renderer, btn ∗screen_buttons, TTF_Font ∗title_font, TTF_Font ∗body_font)
- void drawOptionsScreen (SDL_Renderer ∗renderer, btn ∗screen_buttons, TTF_Font ∗title_font, TTF_Font ∗body_font, lsystem ∗lsys)
- void drawDrawingScreen (SDL_Renderer ∗renderer, btn ∗screen_buttons, TTF_Font ∗title_font, TTF_Font ∗body_font, lsystem ∗lsys)
- int homeScreenClick (SDL_Renderer ∗renderer, SDL_Event event, btn ∗button_list, int win_flag)
- int optionsScreenClick (SDL_Renderer ∗renderer, SDL_Event event, btn ∗button_list, int win_flag, lsystem ∗lsys)
- int drawScreenClick (SDL_Renderer ∗renderer, SDL_Event event, btn ∗button_list, int win_flag, lsystem ∗lsys, TTF_Font ∗title_font, TTF_Font ∗body_font)
- void createHomeButton (btn ∗screen, TTF_Font ∗font)
- void createBackButton (btn ∗screen, TTF_Font ∗font)
- void addButton (btn ∗button_array, coordinate pos, int width, int height, SDL_Colour colour, TTF_Font ∗font, char ∗text)
- void drawTextToRenderer (SDL_Renderer ∗renderer, int x_pos, int y_pos, char ∗text, TTF_Font ∗font, int allignment)
- void drawButtonToRenderer (SDL_Renderer ∗renderer, btn ui_button)
- void drawAllButtonsToRenderer (SDL_Renderer ∗renderer, btn ∗screen, int len)
- void drawColourChartToRenderer (SDL_Renderer ∗renderer, int x_pos, int y_pos)

- void drawInputColourBox (SDL_Renderer ∗renderer, SDL_Colour colour, int x_pos, int y_pos)
- void drawInfoToRenderer (SDL_Renderer ∗renderer, int x_pos, int y_pos, lsystem lsys, TTF_Font ∗title_font, TTF_Font ∗body_font)
- void drawLine (SDL_Renderer ∗renderer, coordinate start, coordinate end, int x_max, int x_min, int y_max, int y_min)
- void drawFractal (SDL_Renderer ∗renderer, int length, line ∗line_list, SDL_Colour line_colour)
- void printRule (SDL_Renderer ∗renderer, int x_pos, int y_pos, char ∗original, char ∗replacement, TTF_Font ∗font)
- int clickInButton (SDL_Event event, btn screen_button)
- SDL_Colour getPixelColour (SDL_Renderer ∗renderer, int win_width, int win_height, int x_pos, int y_pos)
- void drawBG (SDL_Renderer ∗renderer)
- void imgSave (SDL_Renderer ∗renderer, lsystem ∗lsys)
- void sequenceSave (SDL_Renderer ∗renderer, lsystem ∗lsys, TTF_Font ∗title_font, TTF_Font ∗body_font)

### 4.5.1 Detailed Description

File containing source code for all UI functions.

The first half of the functions defined in the file are specific to the drawsystem program, containing instructions on creating, drawing and handeling clicks on the various screens used by the program. The second half of the file contains genral UI functions used by the program specific functions.

### 4.5.2 Function Documentation

#### 4.5.2.1 void createHomeScreenButtons ( **btn** ∗ *screen_buttons,* TTF_Font ∗ *font* )

Defines all of the buttons that will appear on the home screen.

An array of buttons is created that can be passed to both the screen drawing functions and the click handeling functions so that they are both looking at the same array of buttons. This makes updating, changing and adding to the buttons that appear on each screen much easier.

**Parameters**

| | | |
|---|---|---|
| out | *screen_buttons* | a structure that will hold information on buttons to appear on the home screen. |
| in | *font* | font for the button lables. |

#### 4.5.2.2 void createOptionsScreenButtons ( **btn** ∗ *screen_buttons,* TTF_Font ∗ *font* )

Defines all of the buttons that will appear on the options screen.

An array of buttons is created that can be passed to both the screen drawing functions and the click handeling functions so that they are both looking at the same array of buttons. This makes updating, changing and adding to the buttons that appear on each screen much easier.

**Parameters**

| | | |
|---|---|---|
| out | *screen_buttons* | a structure that will hold infromation on buttons to appear on the options screen. |
| in | *font* | font for the button lables. |

#### 4.5.2.3 void createDrawScreenButtons ( **btn** ∗ *screen_buttons,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font* )

Defines all of the buttons that will appear on the options screen.

An array of buttons is created that can be passed to both the screen drawing functions and the click handeling functions so that they are both looking at the same array of buttons. This makes updating, changing and adding to the buttons that appear on each screen much easier.

**Parameters**

| | |
|---|---|
| *screen_buttons* | an array that will hold infromation on buttons to appear on the draw screen. |
| *title_font* | large font to be used on some buttons. |
| *body_font* | small font to be used on some buttons. |

#### 4.5.2.4 void drawHomeScreen ( SDL_Renderer ∗ *renderer,* btn ∗ *screen_buttons,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font* )

Draws the home sceen to the renderer.

draws the background colour to the renderer, then all the buttons defined in the btn array and then some title text.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for screen to be drawn to. |
| in | *screen_buttons* | buttons to be drawn to the screen. |
| in | *title_font* | font for the title text |
| in | *body_font* | font for the body text. |

#### 4.5.2.5 void drawOptionsScreen ( SDL_Renderer ∗ *renderer,* btn ∗ *screen_buttons,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font,* lsystem ∗ *lsys* )

Draws the options screen to the renderer.

Sraws the background, then some title text, then colour charts for picking drawing colours, then the buttons defined in the btn array and finally some text to indicate the current L-System loaded into the lsystem structre.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for screen to be drawn to. |
| in | *screen_buttons* | buttons to be drawn to the screen. |
| in | *title_font* | font to be used for the title text. |
| in | *body_font* | font to be used for the body text. |
| out | *lsys* | lsystem container that has drawing information to be changed byt options buttons. |

#### 4.5.2.6 void drawDrawingScreen ( SDL_Renderer ∗ *renderer,* btn ∗ *screen_buttons,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font,* lsystem ∗ *lsys* )

Sraws the drawing screen to the renderer.

Starts by drawing the background to the renderer, then buttons, instruction text and finally the lsystem drawign window. The drawing of the window runs the functions defined in lsys.c and turtle.c if the relevant flags are set to create the string, and then the line list that are required to draw the lsystem.

To allow the buttons to update the screen live the lsystem needs to be redrawn each frame. To keep the speed up and minimize the number of calultions being done by the computer flags are set to tell the program when the string and line list need to be recalulated and when it can just redraw the last ones that is used (which are stored in the lsystem stucture).

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for the screen to be drawn to. |
| in | *screen_buttons* | buttons to be drawn to the screen. |

| | | |
|---|---|---|
| `in` | *title_font* | font to be used for the title text. |
| `in` | *body_font* | font to be used for the body text. |
| `out` | *lsys* | lsystem that contains information to be drawn to the screen. |

#### 4.5.2.7 int homeScreenClick ( SDL_Renderer ∗ *renderer,* SDL_Event *event,* btn ∗ *button_list,* int *win_flag* )

Handles what happens when a button is clicked by checking the position against buttons defined in the button list.

The position of the click is checked against each button in the array and if it is inside one of these then the relevant value is returned.

**Parameters**

| | | |
|---|---|---|
| `in` | *event* | a click event that contains infromation about which mouse button was pressed and where. |
| `in` | *win_flag* | a flag that indicates which window is currently being sent to the screen (main menu, creation options, display lsystem ect.). |
| `in` | *button* | an array of the buttons that are on the screen. |
| `in` | *win_flag* | the old window flag. |

**Returns**

the new win_flag that will indicate what the new window should be (default is the same value that came in).

#### 4.5.2.8 int optionsScreenClick ( SDL_Renderer ∗ *renderer,* SDL_Event *event,* btn ∗ *button_list,* int *win_flag,* lsystem ∗ *lsys* )

Handles what happens when a button is clicked by checking the position against buttons on the current screen (which is indicated by the win_flag).

The position of the click is checked against each button in the array and if it is inside one of these then the relevant value is returned and changes made to the lsystem structure.

**Parameters**

| | | |
|---|---|---|
| `in` | *event* | a click event that contains infromation about which mouse button was pressed and where. |
| `in` | *win_flag* | a flag that indicates which window is currently being sent to the screen (main menu, creation options, display lsystem ect.). |
| `in` | *button_list* | an array of the buttons that are on the screen. |
| `in` | *win_flag* | the old window flag. |
| `in` | *lsys* | container for information about the lsystem, which will be edited depending on the options chosen. |

**Returns**

the new win_flag that will indicate what the new window should be (default is the same value that came in).

#### 4.5.2.9 int drawScreenClick ( SDL_Renderer ∗ *renderer,* SDL_Event *event,* btn ∗ *button_list,* int *win_flag,* lsystem ∗ *lsys,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font* )

Handles what happens when a button is clicked by checking the position against buttons on the current screen (which is indicated by the win_flag).

the position of the click is checked against each button in the array and if it is inside one of these then the relevant value is returned and flags set.

**Parameters**

| | | |
|---|---|---|
| in | *event* | a click event that contains infromation about which mouse button was pressed and where. |
| in | *win_flag* | a flag that indicates which window is currently being sent to the screen (main menu, creation options, display lsystem ect.). |
| in | *button* | an array of the buttons that are on the screen. |
| in | *win_flag* | the old window flag. |
| out | *lsys* | container for information about the lsystem, which will be edited depending on the options chosen. |
| in | *tile_font* | large font used in the save sequence button. |
| in | *body_font* | small font used in the save sequence button. |

**Returns**

the new win_flag that will indicate what the new window should be (default is the same value that came in).

#### 4.5.2.10 void createHomeButton ( btn ∗ *screen,* TTF_Font ∗ *font* )

Adds a home button to the input btn array which makes up a screen.

Every screen will have a home button in the same place that looks the same to help make the program feel continuous.

**Parameters**

| | | |
|---|---|---|
| out | *screen* | the screen that the home button is to be added to. |
| in | *font* | font for the text on the home button. |

#### 4.5.2.11 void createBackButton ( btn ∗ *screen,* TTF_Font ∗ *font* )

Adds a back button to the input screen.

Every screen will have a back button in the same place that looks the same to help make the program feel continuous.

**Parameters**

| | | |
|---|---|---|
| out | *screen* | the screen that the back button is to be added to. |
| in | *font* | font for the text on the home button. |

#### 4.5.2.12 void addButton ( btn ∗ *button_array,* coordinate *pos,* int *width,* int *height,* SDL_Colour *colour,* TTF_Font ∗ *font,* char ∗ *text* )

A function that sets the variable for the button structure taken as input.

**Parameters**

| | | |
|---|---|---|
| out | *button* | button that is to hold the information. |
| in | *pos* | position of the top left corner of the button. |
| in | *width* | width of the button. |
| in | *height* | height of the button. |
| in | *colour* | colour of the button. |

| | | |
|---|---|---|
| in | *font* | font for the button text. |
| in | *text* | string containing the lable for the button. |

#### 4.5.2.13 void drawTextToRenderer ( SDL_Renderer ∗ *renderer*, int *x_pos*, int *y_pos*, char ∗ *text*, TTF_Font ∗ *font*, int *allignment* )

Wraps up all of the SDL and SDL_ttf functions required for drawing to the renderer and brings them together into an easy to use function.

To draw text to the renderer, the text must be created as a surface, then copied to a texture which can then be copied to a renderer inside a rectangle that is the same size as the texture. This function wraps this proces up and also allows a flag to be set for text allignment to make positioning easier for the user.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | pointer to the renderer that will hold the output. |
| in | *x_pos* | x position for the text on the renderer. |
| in | *y_pos* | y position for the text on the renderer. |
| in | *text* | character array for the text to be written to the renderer. |
| in | *font* | the font for the text to be written. |
| in | *allignment* | an option for thext allignment, 0 is centered, 1 is left alligned and 2 is right alligned in relation to the input coorinates. |

#### 4.5.2.14 void drawButtonToRenderer ( SDL_Renderer ∗ *renderer*, btn *ui_button* )

draws a single button to the renderer

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | The renderer that the button is to be drawn to. |
| in | *ui_button* | a structure that holds information on the button to be drawn. |

#### 4.5.2.15 void drawAllButtonsToRenderer ( SDL_Renderer ∗ *renderer*, btn ∗ *screen*, int *len* )

Runs through the button list that mekes up a screen and prints each one to the renderer if it exists.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for buttons to be drawn to. |
| in | *screen* | array contianing buttons to be drawn to the renderer. |
| in | *len* | number of buttons in the btn array. |

#### 4.5.2.16 void drawColourChartToRenderer ( SDL_Renderer ∗ *renderer*, int *x_pos*, int *y_pos* )

Draws a colour selection chart to the rendenderer.

To crate a colour selection chart for the user to use, red, green and blue variables are initialised, and then cycled through in multiples of 51 in nested for loops to create a distribution of colours. This creates 6 different values for each colour chanel, resulting in 216 colours to chooe from. Each colour is then drawn in its own box on the renderer and after evey 6 blocks a new line is started.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | pointer to the renderer that is to be drawn to. |
| in | *x_pos* | x position of the top left-hand corner of the chart. |
| in | *y_pos* | y position of the top left_hand corner of the chart. |

#### 4.5.2.17 void drawInputColourBox ( SDL_Renderer ∗ *renderer,* SDL_Colour *colour,* int *x_pos,* int *y_pos* )

A function for drawing a coloured box to the screen.

Used for displaying the current line and background colours before drawing the fractal to the renderer.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for box to be drawn to. |
| in | *colour* | colour that the box will be. |
| in | *x_pos* | x position for the top left corner of the box. |
| in | *y_pos* | y position for the top left corner of the box. |

#### 4.5.2.18 void drawInfoToRenderer ( SDL_Renderer ∗ *renderer,* int *x_pos,* int *y_pos,* lsystem *lsys,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font* )

displays information about the lsystem being drawn to the screen.

If the display_info flag is true, then information about the lsystem will be drawn to the renderer as well as the fractal its self. This info will also be present in the saved images if it is on the screen at the time of the save button being pressed.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for information to be drawn to. |
| in | *x_pos* | x coordinate of top left corner of info box. |
| in | *y_pos* | y coordinate of top left corner of info box. |
| in | *lsys* | lsystem containing information to be printed. |
| in | *title_font* | large font. |
| in | *body_font* | small font. |

#### 4.5.2.19 void drawLine ( SDL_Renderer ∗ *renderer,* coordinate *start,* coordinate *end,* int *x_max,* int *x_min,* int *y_max,* int *y_min* )

A line drawing function that implements the bresenheim line drawing algorithm to draw a line between two points.

Based on source code from Eike Anderson, Computing for Graphics level c, lecture 19, 2015. Edited to work with struct Coordinate as start and end points for line. I felt it was necessary to write my own (as opposed to using th SDL_RederDrawLine() function) as I could therefor check the pixels being drawn to on a point by point basis so that I could constrain the drawing to a box on the screen while not having to miss out whole lines.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | target to be rendered to. |
| in | *start* | start point for the line. |
| in | *end* | end point of the line. |
| in | *x_max* | maximum x coordinate to draw to. |
| in | *x_min* | minimum x coordinate to draw to. |
| in | *y_max* | maximum y coordinate to draw to. |

| | | |
|---|---|---|
| in | *y_min* | minimum y coordinate to draw to. |

#### 4.5.2.20 void drawFractal ( SDL_Renderer ∗ *renderer,* int *length,* line ∗ *line_list,* SDL_Colour *line_colour* )

Draws the fractal storred as int line_list which is of length 'length'

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer to be drawn to. |
| in | *length* | number of items in the line list. |
| in | *line_list* | a list of coordinate pairs whcih define the lines that need to be drawn. |
| in | *line_colour* | colour for the lines to be drawn. |

#### 4.5.2.21 void printRule ( SDL_Renderer ∗ *renderer,* int *x_pos,* int *y_pos,* char ∗ *original,* char ∗ *replacement,* TTF_Font ∗ *font* )

Formats and writes out the rule for the input character.

For printing the rules to the drawing screen, the strings needed to be specifically formatted and this function wraps up that formatting.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for the rule to be written to. |
| in | *x_pos* | x position for the top left hand corner of the text. |
| in | *y_pos* | y position of the top left hand corner of the text. |
| in | *original* | the character that is to be replaced in a string format. |
| in | *replacement* | the replacement string for that character. |
| in | *body_font* | the font to be used. |

#### 4.5.2.22 int clickInButton ( SDL_Event *event,* btn *screen_button* )

checks to see if a click happened inside a specific button.

Uses the button to calulate upper and lower boundaries for x and y positions that fall inside the button and then gets the click event data and compares the position to these limits. Includes a safety check to make sure that the event is a click event.

**Parameters**

| | | |
|---|---|---|
| in | *event* | the click event in question. |
| in | *screen_button* | the button that contains the information on the position of the window. |

**Returns**

true (1) if click is inside the button, fase (0) if not.

#### 4.5.2.23 SDL_Colour getPixelColour ( SDL_Renderer ∗ *renderer,* int *win_width,* int *win_height,* int *x_pos,* int *y_pos* )

Finds the pixel colour on the renderer of the point given by x_pos, y_pos.

Based on source code from Eike Anderson, Computing for Graphics level c,

1. Edited to work with struct SDL_Colour. It works by firstly ckecking to make sure that the click was inside the window, then, if it was, a helper surface is created and then reformatted to take the information retrieved from

the renderer using SDL_RenderReadPixels. The RGB values from this data is then copied into the p_colour variable that is then returned.

**Parameters**

| | | |
|---|---|---|
| in | *renderer* | renderer that holds the pixel information. |
| in | *win_width* | width of the window (used to make sure the pixel piosition exists). |
| in | *win_height* | height of the window (used to make sure the pixel position exists). |
| in | *x_pos* | x coordinate of the pixel being looked at. |
| in | *y_pos* | y coordinate of the pixel beign looked at. |

**Returns**

the colour of the pixel in rgba format.

#### 4.5.2.24 void drawBG ( SDL_Renderer ∗ *renderer* )

Draws background to renderer.

clears the background to a single colour and then draws a menu bar in a different colour to the top of the renderer.

**Parameters**

| | | |
|---|---|---|
| out | *renderer* | renderer for the bakkground to be drawn to |

#### 4.5.2.25 void imgSave ( SDL_Renderer ∗ *renderer,* lsystem ∗ *lsys* )

Saves the fractal image as a single bmp image.

Copies the drawing region of the renderer to a surface to be saved by the SDL_SaveBMP() function.

**Parameters**

| | | |
|---|---|---|
| in | *renderer* | renderer that contains onformation to be copied |
| in | *lsys* | the structure that contains the information for naming |

#### 4.5.2.26 void sequenceSave ( SDL_Renderer ∗ *renderer,* lsystem ∗ *lsys,* TTF_Font ∗ *title_font,* TTF_Font ∗ *body_font* )

Saves the fractal as a sequence of bmp images that show the fractal being drawn line by line.

clears the renderer before iteratively drawing lines to it, then converting to surface and saving. The program splits up the lines being drawn so that there is a limit of 100 frames that can be saved. this keeps the program running quickly but limits what the user can do with the output. I decided on doing it this way because the save sequence is error porne and slow (moving the window while saving off a sequence causes artifacts).

**Parameters**

| | | |
|---|---|---|
| in | *lsys* | structure that contians information for drawing img sequence. |

# Index

addButton
    ui.c, 23

btn, 5

clickInButton
    ui.c, 26
coordinate, 5
countMoves
    turtle.c, 18
createBackButton
    ui.c, 23
createDrawScreenButtons
    ui.c, 19
createHomeButton
    ui.c, 23
createHomeScreenButtons
    ui.c, 19
createOptionsScreenButtons
    ui.c, 19

dragon
    lsys.c, 12
drawAllButtonsToRenderer
    ui.c, 24
drawBG
    ui.c, 28
drawButtonToRenderer
    ui.c, 24
drawColourChartToRenderer
    ui.c, 24
drawDrawingScreen
    ui.c, 21
drawFractal
    ui.c, 26
drawHomeScreen
    ui.c, 21
drawInfoToRenderer
    ui.c, 25
drawInputColourBox
    ui.c, 25
drawLine
    ui.c, 25
drawOptionsScreen
    ui.c, 21
drawScreenClick
    ui.c, 22
drawTextToRenderer
    ui.c, 24
dtor
    lsys.c, 10

getPixelColour
    ui.c, 26
gosper
    lsys.c, 13

homeScreenClick
    ui.c, 22

imgSave
    ui.c, 28
init
    main.c, 14
initLsystem
    lsys.c, 10
islands
    lsys.c, 13
iteration
    lsys.c, 10

line, 6
lsys.c
    dragon, 12
    dtor, 10
    gosper, 13
    initLsystem, 10
    islands, 13
    iteration, 10
    makeString, 10
    plant1, 12
    plant2, 12
    quadKoch, 13
    resetLines, 12
    resetString, 12
    rtod, 10
    sierpinski, 12
    snowflake, 13
lsystem, 6

main
    main.c, 14
main.c
    init, 14
    main, 14
makeString
    lsys.c, 10

optionsScreenClick
    ui.c, 22

penDownLine
    turtle.c, 17
penUpLine
    turtle.c, 17
plant1
    lsys.c, 12
plant2
    lsys.c, 12
popPos
    turtle.c, 17
printRule
    ui.c, 26

quadKoch
    lsys.c, 13

resetLines
    lsys.c, 12
resetString
    lsys.c, 12
rtod
    lsys.c, 10

savePos
    turtle.c, 17
sequenceSave
    ui.c, 28
sierpinski
    lsys.c, 12
snowflake
    lsys.c, 13
src/lsys.c, 9
src/main.c, 13
src/structs.c, 14
src/turtle.c, 16
src/ui.c, 18
stringToTurtle
    turtle.c, 16
structInitBtn
    structs.c, 15
structInitCoord
    structs.c, 15
structInitLine
    structs.c, 15
structInitLsystem
    structs.c, 15
structInitTurtleState
    structs.c, 15
structs.c
    structInitBtn, 15
    structInitCoord, 15
    structInitLine, 15
    structInitLsystem, 15
    structInitTurtleState, 15

turtle.c
    countMoves, 18
    penDownLine, 17
    penUpLine, 17
    popPos, 17
    savePos, 17
    stringToTurtle, 16
turtle_state, 7

ui.c
    addButton, 23
    clickInButton, 26
    createBackButton, 23
    createDrawScreenButtons, 19
    createHomeButton, 23
    createHomeScreenButtons, 19
    createOptionsScreenButtons, 19
    drawAllButtonsToRenderer, 24
    drawBG, 28
    drawButtonToRenderer, 24
    drawColourChartToRenderer, 24
    drawDrawingScreen, 21
    drawFractal, 26
    drawHomeScreen, 21
    drawInfoToRenderer, 25
    drawInputColourBox, 25
    drawLine, 25
    drawOptionsScreen, 21
    drawScreenClick, 22
    drawTextToRenderer, 24
    getPixelColour, 26
    homeScreenClick, 22
    imgSave, 28
    optionsScreenClick, 22
    printRule, 26
    sequenceSave, 28