Wefx

The Wefx Devs

2022-08-04

Contents

1 wefx

Wefx is a simple graphics library for drawing using C, WASM (Web Assembly), and an HTML canvas. It aims to serve a similar to gfx, but provide an introduction to using C and WASM. Wefx is meant to be a teaching / learning tool for C and graphics. Wefx is not using OpenGL / WebGL or anything like that. It is doing very basic pixel manipulation and has very simple functions to draw pixels and lines.

If you would like to see an overview of Wefx, you can watch a video of the project on YouTube

You can also download the documentation

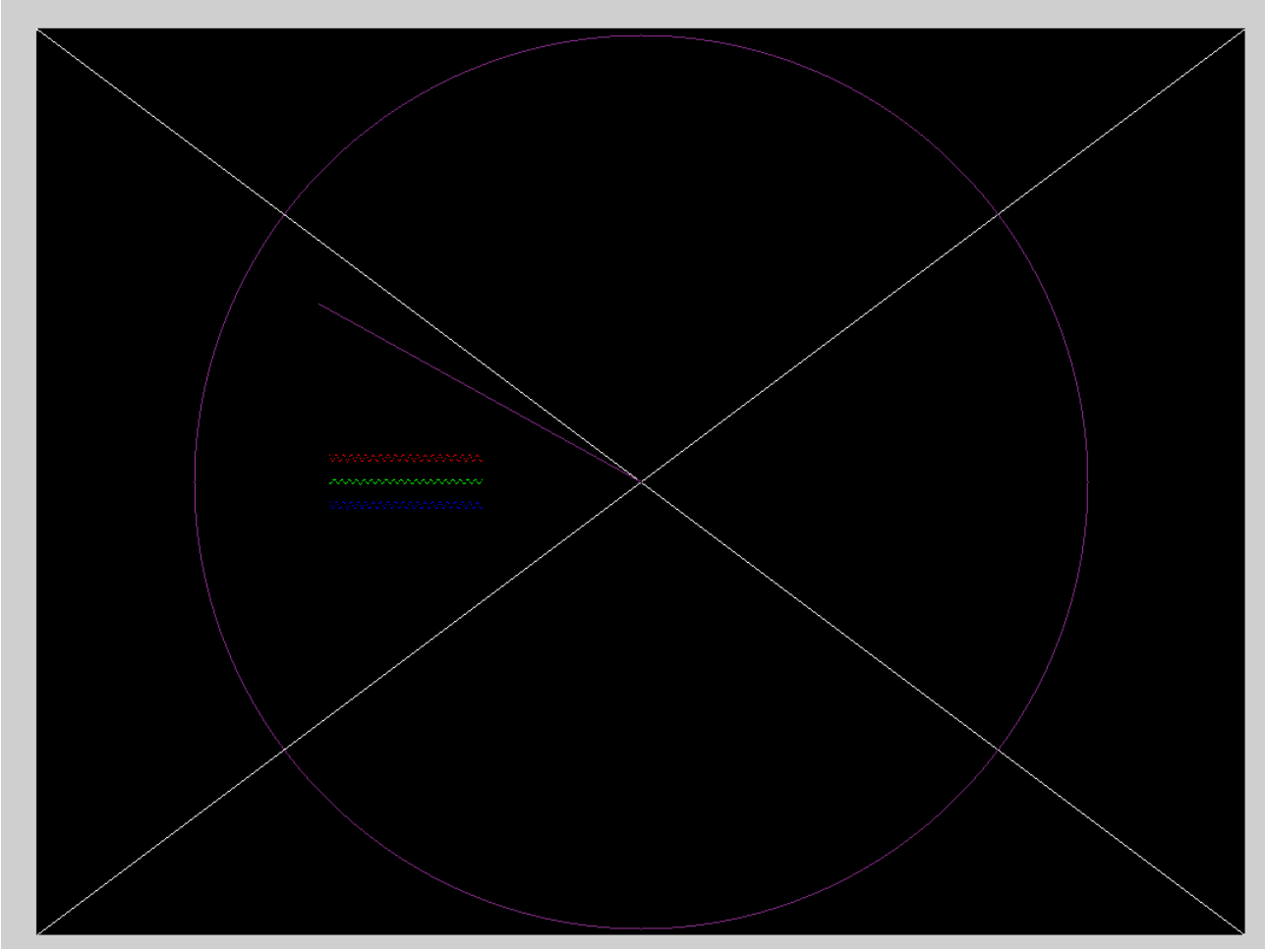
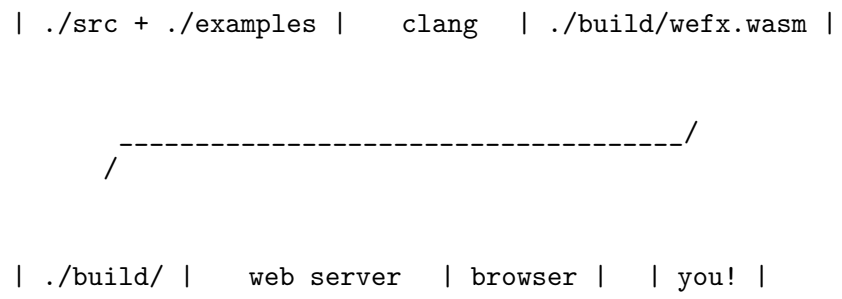


Figure 1: Example Screenshot

1.1 Using The Project

The flow of the project has two steps: the build step, and the serve step:



In other words, you compile the C code into a WASM, and then serve the `build` directory using a web server. You can then open a web browser and visit http://localhost:8000 to view the running C code.

You'll need the following programs installed:

- clang
- make (optional - MacOS and Linux)
- (optional) python3

On MacOS or Linux these tools should be available already, or easily installed with homebrew (`brew install`), or Apt (`apt install`), or your local package manager.

1.1.1 Compiling

To understand what is happening (or if you do not want to use *make*), open the *Makefile* file and look at the *build* task. There you can see how *clang* is used.

If you have *make* available, type:

```
make build
```

on the command line. This will, assuming there are no errors, create the file `./build/wefx.wasm`. Once this builds you can serve your creation by doing the following…

1.1.2 Serving

The gist of this is you need to serve the contents of the `/build` directory in a web server. You need to do this because the file that loads the newly create `wasm` file (index.html can only load the wasm file over http. You can not simply open the `index.html` file directly from your file system (this is just how wasm loading works).

If you try to open the `index.html` file directly you will get an error like:

```
Cross-Origin Request Blocked: The Same Origin Policy disallows reading the remote resource at
```

A basic http server comes with python3, and the make file will run that server if you run:

```
make serve
```

and the python3 web server will serve the files in the *build* directory. You can then use your favorite browser and browse to http://localhost:8000 to see the compiled code.

Note `make serve` will both recompile your code and run the web server.

If you already have a favorite server (for example I use busboy), you can use that serve to serve the `build` directory instead, and then run the `make build` command to replace the wasm file as you play around.

For example in one shell I run:

```
busyboy --root=./build
```

Then, after I make changes to the C code, I run

```
make build
```

And then simply refresh the browser to see changes.

1.1.3 Writing Code

If just teaching / learning about graphics, you'll only need to edit the ./examples/example0.c file. There are two entry points into that file:

Function	Usage
init()	Called once at the start of the app
main_loop(time)	Called every frame with time being time since app start

You can also add your own files entry files in the examples directory, and then pass them to the build script using the *MAIN* variable. For example:

```
make build MAIN=examples/example1.c
```

will build the WASM file using `example1.c` as the entry point.

1.1.4 API: Getting Started

The API calls try to emulate gfx as much as possible. Here are a few currently supported functions (see the documentation for a full reference):

Function	Does
wefx_open(width, height, title)	Create a canvas on which to draw
wefx_clear_color(red, green, blue)	Set the background color
wefx_color(red, green, blue)	Set the drawing color
wefx_point(x, y)	Draw a single point
wefx_line(x1, y1, x2, y2)	Draw a line from (x1,y1) to (x2,y2)
wefx_clear()	Clear the canvas using the background color

1.1.5 Windows OS

I have not run this on Windows, but you should be able to build it with Visual Studio. You will have to install `clang` as an add on, and then setup the build flags to the ones shown in the `Makefile`.

2 Wefx Drawing

A simple graphics library made in the spirit of gfx

To start out, we import our *wefx.h* header file. This file contains a few structs, and enumerations we will be using throughout this implementation file.

```
#include "wefx.h"
```

Additionally, we include our *wasm.h* file which will allow us to *EXPORT* functions and variables to Javascript.

```
#include "wasm.h"

typedef unsigned int color;
```

Make variables for our double buffered screen, and export the *screen* variable so Javascript can use it's contents to create an image.

```
EXPORT unsigned int *screen;
static unsigned int *buffer;
```

We also defined some global variables for foreground and background colour, as well as a global width (w) and height (h) variable.

```
static color fg_color = 0;
static color bg_color = 0;
static int w = 0;
static int h = 0;
```

Lastly, we reserve a spot for an event queue where we will store user events from the browser. E.g. Mouse down, mouse move, key down, etc.

```
wefx_event_queue *wefx_q = NULL;
```

2.1 Opening a Canvas - wefx_open

Here we emulate opening a window. This allocates memory for our screen buffer.

```
int wefx_open(unsigned int width, unsigned int height, const char *title)
{
    w = width;
    h = height;
    buffer = malloc(w * h * sizeof(int));
    if (buffer == NULL)
    {
        return 1;
    }
    return 0;
}
```

2.2 Convert Integers to RGB - rgb_to_int

Since we have have a few functions that deal with colors, we create an internal function that will help convert three RGB values into a single integer value. This value will go directly into the screen buffer to represnet a pixel color.

When we are given three values to represent RGB, we shift the colors up into a single integer. Note we need to ensure the values are not greater than 255 since we are only supporting RGB value from within that range.

In the end, the integer will look like the following (in hexidecimal):

alpha	blue	green	red
0xFF	FF	FF	FF

from within a single integer.

```
static int rgb_to_int(unsigned int red, unsigned int green, unsigned int blue)
{
    if (red > 255)
        red = 255;
    if (green > 255)
        green = 255;
    if (blue > 255)
        blue = 255;
    int color = (0xFF << 24) + (blue << 16) + (green << 8) + (red);
    return color;
}
```

2.3 Set the Foreground Color - wefx_color

This function simply sets our *fg_color* variable to the specified color.

Subsequent calls to draw will use this color until it is changed.

```
void wefx_color(unsigned int red, unsigned int green, unsigned int blue)
{
    fg_color = rgb_to_int(red, green, blue);
}
```

2.4 Draw a Single Point - wefx_point

This function sets one pixel value to a color. It set one of the values in our *buffer* array to the current value stored *fg_color*.

By setting the value at $x + y * w$ we are drawing a point at (x, y) on the screen.

```
void wefx_point(int x, int y)
{
    buffer[x + y * w] = fg_color;
}
```

2.5 Set the Background Color - wefx_clear_color

This color will be used as the background color for the image. Call this to set the background color, and then by calling *wefx_clear*, you can fill the entire screen buffer.

```
void wefx_clear_color(unsigned int red, unsigned int green, unsigned int blue)
{
    bg_color = rgb_to_int(red, green, blue);
}
```

2.6 Clear the Screen - wefx_clear

This function will "clear the screen". What it actually does is fill the whole screen buffer with the current background color (see wefx_clear_color).

This is often called at the top of the render loop to reset to a blank slate before doing any drawing.

```
void wefx_clear()
{
    for (int q = 0; q < w * h; q++)
        buffer[q] = bg_color;
}
```

2.7 Draw a Line - wefx_line

Here we define a simple function to draw a line. It will draw from (x1,y1) to (x2,y2) using Bresenham's line algorithm[1] and the currently set foreground color.

```
void wefx_line(int x0, int y0, int x1, int y1)
{
    int dx = abs(x1 - x0);
    int sx = x0 < x1 ? 1 : -1;
    int dy = -abs(y1 - y0);
    int sy = y0 < y1 ? 1 : -1;
    int error = dx + dy;

    for (;;)
    {
        wefx_point(x0, y0);
        if (x0 == x1 && y0 == y1)
            break;
        int e2 = 2 * error;
        if (e2 >= dy)
        {
            if (x0 == x1)
                break;
            error = error + dy;
            x0 = x0 + sx;
        }
```

[1] You can read more about Bresenham's line algorithm here https://en.wikipedia.org/wiki/Bresenham%27s_line_algorithm

```
        if (e2 <= dx)
        {
            if (y0 == y1)
                break;
            error = error + dx;
            y0 = y0 + sy;
        }
    }
}
```

2.8 Draw a Circle - wefx_circle

This function can be called to draw a circle. It also uses the currently set forground color. I uses the Midpoint Circle Algorithm[2]

```
void wefx_circle(int x0, int y0, int r0)
{
    int x = r0;
    int y = 0;
    int err = 0;
    while (x >= y)
    {
        wefx_point(x0 + x, y0 + y);

        wefx_point(x0 + y, y0 + x);
        wefx_point(x0 - y, y0 + x);
        wefx_point(x0 - x, y0 + y);
        wefx_point(x0 - x, y0 - y);
        wefx_point(x0 - y, y0 - x);
        wefx_point(x0 + y, y0 - x);
        wefx_point(x0 + x, y0 - y);

        y += 1;
        err += 2 * y + 1;
        if (err > 0)
        {
            x -= 1;
            err -= 2 * x + 1;
        }
    }
}
```

2.9 Draw the Buffer to Screen

When we call any of the wefx draw functions, we are actually changing the pixels in a buffer. They pixels we are setting are not actually drawn to the screen.

This method is called from Javascript and asks us to draw our buffer to what it considers to be the screen.

[2]You can read more about the Midpoint Circle Algorithm here https://en.wikipedia.org/wiki/Midpoint_circle_algorithm

---

Note: there might be a faster / better way to do this.

```
EXPORT void wefx_draw(unsigned int *screen)
{
    for (int q = 0; q < w * h; q++)
        screen[q] = buffer[q];
}
```

2.10 Get Screen Dimensions

Javascript will need to know what size we have defined our screen size to be. These methods are exposed to Javascript to get the X and Y dimensions of the buffer / screen.

```
EXPORT int wefx_xsize()
{
    return w;
}
EXPORT int wefx_ysize()
{
    return h;
}
```

3 Event Queue

In order to process browser events (keyboard and mouse input), we use a simple Queue. The Javascript that hosts this code will capture events in the browser and pass them into C using the queue. We can then use the queue to look at and process those events.

3.1 Open Events - wefx_open_events

Similar to how *wefx_open* created screen memory, the *wefx_open_events* function allocates memory for the event queue.

```
wefx_event_queue *wefx_open_events()
{
    wefx_q = malloc(sizeof(struct wefx_event_queue));
    if (wefx_q != NULL)
    {
        wefx_init_queue(wefx_q);
        return wefx_q;
    }

    return NULL;
}
```

When we create a new queue, we want to set the head and tail to null to mark it as empty. This is not strictly necessary, but it will make knowing if the queue is empty a bit easier.

```
void wefx_init_queue(wefx_event_queue *q)
{
    q->head = NULL;
    q->tail = NULL;
}
```

3.2 Add Events from Javascript

Javascript will call this function directly to register that an event has occurred.

Here we just take the parameters passed in from Javascript, put them into the *wefx_event* struct, and add it to the end of the queue.

```
EXPORT void wefx_add_queue_event(int type, int button, int timestamp, int key, int x, int y)
{
    // if we don't care about events drop everything
    if (wefx_q == NULL)
        return;

    wefx_event *e = malloc(sizeof(struct wefx_event));
    if (e == NULL)
    {
        // we couldn't create memory for some reason
        // this seems to happen a bit when running in
        // wasm (or maybe walloc)
        return;
    }
    e->type = type;
    e->button = button;
    e->timestamp = timestamp;
    e->key = (char)key;
    e->x = x;
    e->y = y;

    wefx_enqueue(wefx_q, e);
}
```

3.3 Add an Event to a Queue

wefx_enqueue takes an event and adds it to the given queue. It does a number of checks to make sure the queue is in a valid state, and adds the event if everything is ok.

```
int wefx_enqueue(wefx_event_queue *q, wefx_event *event)
{
    // create a new node to store the event
    wefx_event_node *node = malloc(sizeof(struct wefx_event_node));
    if (node == NULL)
    {
        return -1;
    }

    node->event = event;
```

```
    node->next = NULL;

    // if the queue has a tail, add us as the next behind the tail
    if (q->tail != NULL)
    {
        q->tail->next = node;
    }
    // now really make us the last node
    q->tail = node;

    // if we are first in line, go to the head
    if (q->head == NULL)
    {
        q->head = node;
    }

    return 1;
}
```

3.4 Remove an Event from a Queue

Take the first event in the queue off the queue and return it.

```
wefx_event *wefx_dequeue(wefx_event_queue *q)
{
    if (q == NULL)
        return NULL;

    if (q->head == NULL)
    {
        return NULL;
    }

    wefx_event_node *n = q->head;
    wefx_event *e = n->event;
    q->head = q->head->next;
    if (q->head == NULL)
    {
        q->tail = NULL;
    }

    free(n);
    return e;
}
```

4 Math Functions

First we include the header file which define some constants and macros.

```
#include "math.h"
```

Params for the random number generator (lcg below) See this paper for more info: https://epub.wu.ac.at/1288/1/d

```
#define RND_2_31_MINUS_ONE 2147483647
#define RND_PARK_MILLER 16807
```

4.1 Abs function

```
float abs(float n)
{
    if (n < 0)
        return n * -1;
    return n;
}
```

4.2 Degree To Radians

```
float to_radian(float degree)
{
    return degree * (M_PI / 180);
}
```

4.3 Radians To Degrees

```
float to_degree(float radian)
{
    return radian * (180 / M_PI);
}
```

4.4 Power

```
float pow(float x, float y)
{
    float rtn = x;
    while (y > 1)
    {
        rtn *= x;
        y--;
    }
    return rtn;
}
```

4.5 Floor

```
float floor(float n)
{
    float base = (float)(int)(n - ((int)n % 1));
    if (n < 0)
        return base - 1;
    return base;
}
```

4.6 Ceiling

```
float ceil(float n)
{
    float base = (float)(int)(n - ((int)n % 1));
    if (n > 0)
        return base + 1;
    return base;
}
```

4.7 Round

```
float round(float x)
{
    float m = x - (int)x;
    if (m < 0.5)
        return floor(x);
    return ceil(x);
}
```

4.8 Cosine function

First we define the curve we're going to use to emulate cosine

$$p = \frac{x}{\pi^2}$$

recursively split the line and tilt it so the our fake wave starts and stops at about the right place

$$r = p - 0.25 - \lfloor p + 0.25 \rfloor$$

now put it together and make sure the ends touch

$$y = r \times 16 \times |r - 0.5|$$

```
float cos(float x)
{
    float p = x / M_PI2;
    float r = p - .25 - floor(p + .25);
    float y = r * 16 * (abs(r) - 0.5);
    return y;
}
```

4.9 Sine function

The sine function is just cos shifted on the x axis

$$sin\,(x) = cos\left(x - \frac{\pi}{2}\right)$$

```
float sin(float x)
{
    return cos(x - M_PID2);
}
```

4.10 Seed Random

Here we can seed the random number generator, or just use the default seed if one isn't provided

```
static unsigned int SEED = 9035768;
void srand(unsigned int seed)
{
    SEED = seed;
}
```

4.11 Random

Basic random number generator. Linear congruential generator

If the increment (inc) = 0, the generator is a multiplicative congruential generator (MCG)

If inc != 0, the method is called a mixed congruential generator.

```
static int lcg(int md, int mult, int inc, int seed)
{
    SEED = (mult * seed + inc) % md;
    return SEED;
}

int rand()
{
    return lcg(RND_2_31_MINUS_ONE, RND_PARK_MILLER, 0, SEED);
}
```

5 Malloc Implementation

```
#ifndef WEFX_WALLOC__H
#define WEFX_WALLOC__H

void *malloc(unsigned long);
void free(void *);

#endif /* MALLOC__H */
```

6 Export Function to Javascript

Here we simply define a macro that will let the compiler know that a function should be made available in Javascript.

Prefix functions with the *EXPORT* keyword.

```
#ifndef WEFX_WASM_H
```

```
#define WEFX_WASM_H

#include "math.h"
#include "walloc.h"

// This is used to flag a function as something that
// should be accessible in javascript.
#define EXPORT __attribute__((visibility("default")))

#endif
```