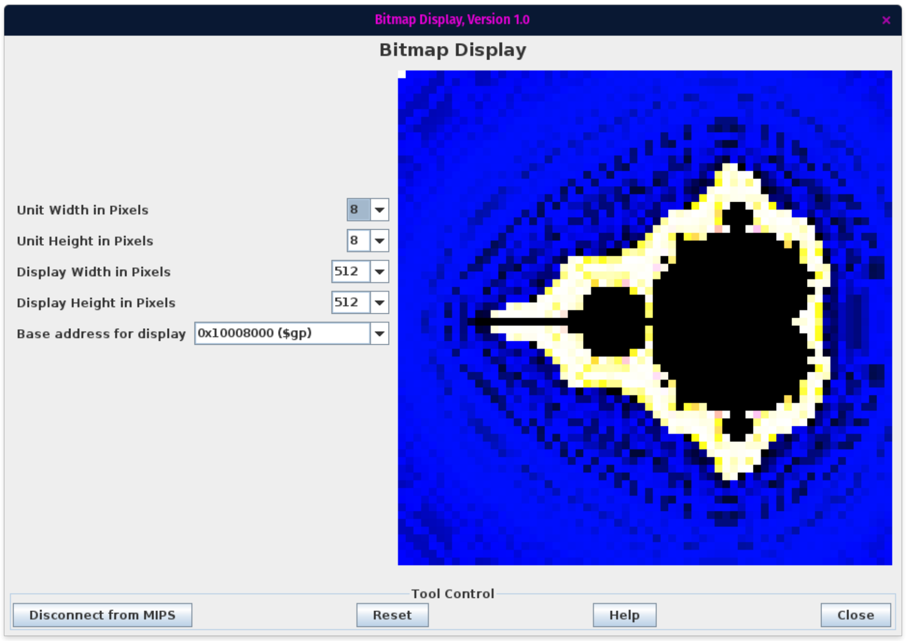
MIPSelbrot

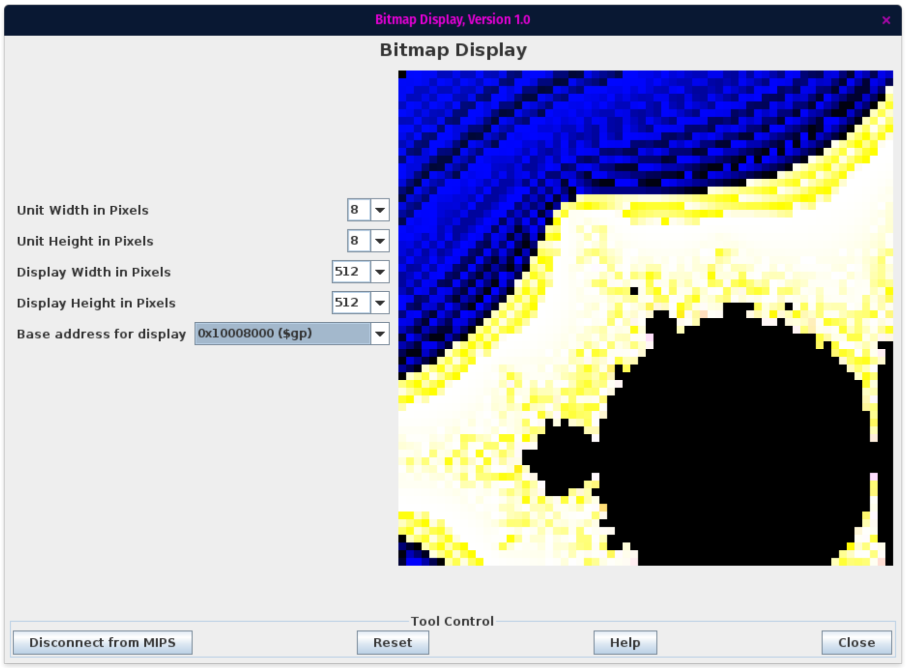
An interactive mandelbrot fractal viewer written in MIPS

https://github.com/CharlesAverill/MIPSelbrot

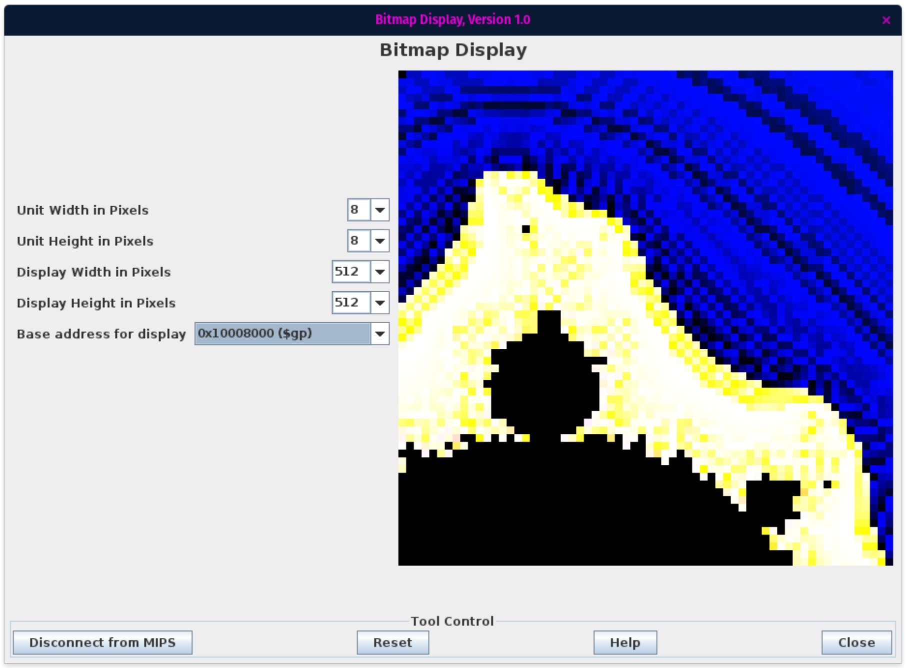
Screenshots



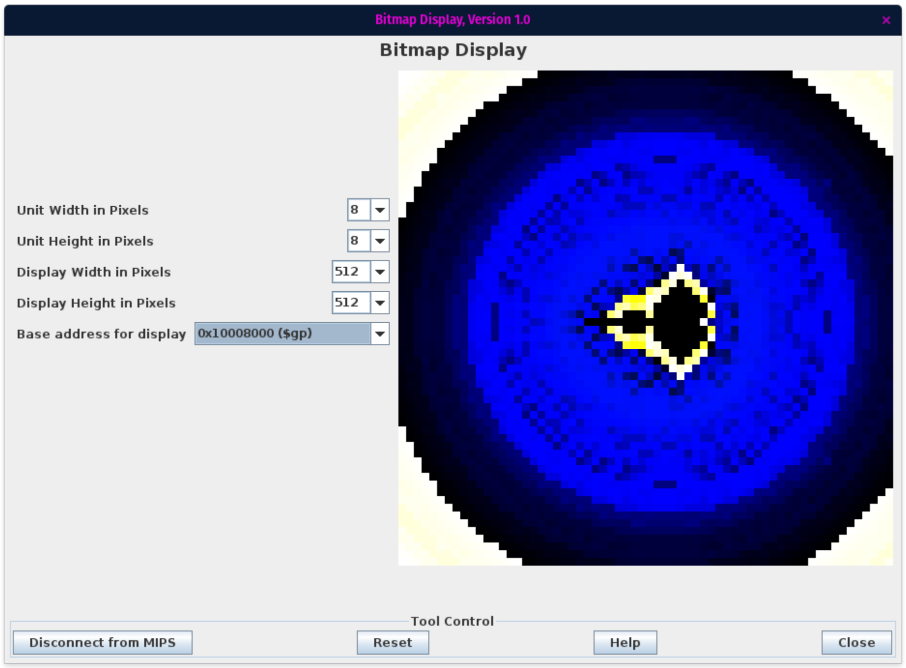
Unit Width in Pixels 8
Unit Height in Pixels 8
Display Width in Pixels 512
Display Height in Pixels 512
Base address for display 0x10008000 ($gp)



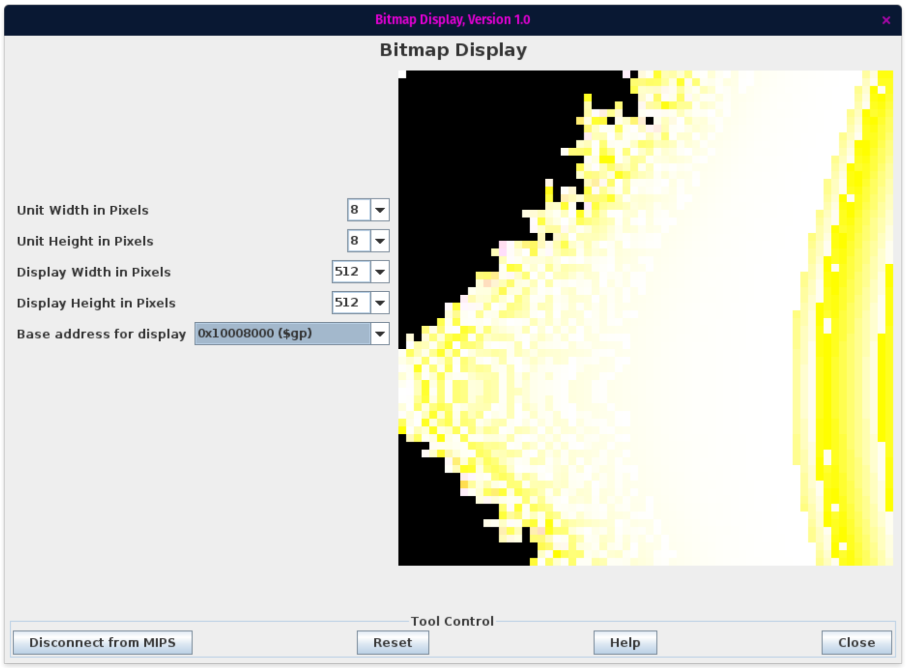
Unit Width in Pixels 8
Unit Height in Pixels 8
Display Width in Pixels 512
Display Height in Pixels 512
Base address for display 0x10008000 ($gp)



Unit Width in Pixels 8
Unit Height in Pixels 8
Display Width in Pixels 512
Display Height in Pixels 512
Base address for display 0x10008000 ($gp)



Unit Width in Pixels 8
Unit Height in Pixels 8
Display Width in Pixels 512
Display Height in Pixels 512
Base address for display 0x10008000 ($gp)



Unit Width in Pixels 8
Unit Height in Pixels 8
Display Width in Pixels 512
Display Height in Pixels 512
Base address for display 0x10008000 ($gp)

Setup

This program was designed to run in the Mars emulator.

- Open the Bitmap Display
- Set the Unit Width and Height to 8
- Set the Display Width and Height to 512
- Set the Base Address for Display to `0x10008000 ($gp)`
- Open the Keyboard and Display MMIO Simulator
- Connect the Bitmap Display and Keyboard Simulator to Mars
- Assemble and Run the program

Usage

The viewer supports the following features via the keyboard

Effect	Command
Translation	Up - "w" Down - "s" Left - "a" Right - "d"
Zoom	In - "z" Out - "x"
Hue Shift	Up - "o" Down - "l"
Brightness Shift	Up - "i" Down - "k"
Toggle sound - default is off, causes significant slowdown	"m"
Exit	"space"

Input is accepted between renders. When a render is complete, the top left pixel will flash black and white.

How does it work?

I used a modified implementation of the smooth coloring algorithm for the general Mandelbrot set. This algorithm uses a concept of "escape velocity" to determine if the coordinates of a pixel fall inside of the Mandelbrot set or not. For each pixel in the image, the scaled coordinates are added to a complex number which is then multiplied by itself. If the product has an absolute value smaller than the escape velocity, then the coordinates are added to the product which is squared again. This iteration repeats until either

1. The absolute value of the product is greater than the escape velocity
2. The iteration count is greater than the escape velocity

If the latter scenario occurs, that pixel is determined to be a part of the Mandelbrot set, which is colored black. If the former occurs, the pixel will be colored proportionally to how many iterations it took to break the escape velocity. To get a color gradient, pixels are split into Blue and Sepia groups depending on their iteration count.

This process is repeated for each pixel in the image. By increasing our escape velocity, we increase the resolution of the set, however the time taken to compute the image increases drastically. I'm using an escape velocity of 100, which is relatively low compared to most plotters, in order to optimize speed.

Certain optimizations are utilized, for example the Mandelbrot set is symmetric about the Real (horizontal) axis, so if `Y_OFFSET == 0`, we only have to render the top half of the image, and then plot the same pixel but mirrored across the center of the screen.

Flowchart

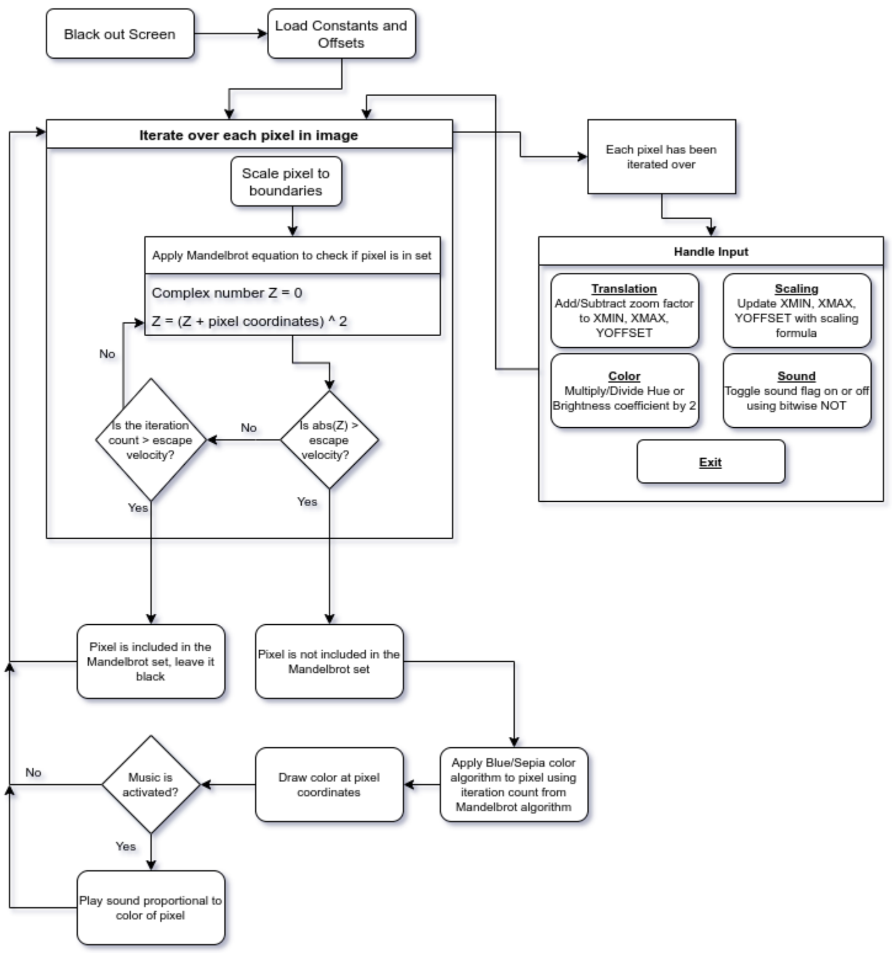

Black out Screen
Load Constants and Offsets
Iterate over each pixel in image
Scale pixel to boundaries
Apply Mandelbrot equation to check if pixel is in set
Complex number Z = 0
Z = (Z + pixel coordinates) ^ 2
No
Is the iteration count > escape velocity?
No
Is abs(Z) > escape velocity?
Yes
Yes
Each pixel has been iterated over
Handle Input
Translation
Add/Subtract zoom factor to XMIN, XMAX, YOFFSET
Scaling
Update XMIN, XMAX, YOFFSET with scaling formula
Color
Multiply/Divide Hue or Brightness coefficient by 2
Sound
Toggle sound flag on or off using bitwise NOT
Exit
Pixel is included in the Mandelbrot set, leave it black
Pixel is not included in the Mandelbrot set
No
Music is activated?
Draw color at pixel coordinates
Apply Blue/Sepia color algorithm to pixel using iteration count from Mandelbrot algorithm
Yes
Play sound proportional to color of pixel

Figure 1: Flowchart

Known Issues

- Zooming does not always put you where you wanted to go, you may end up stuck in a long render loop at the center of the fractal
- Toggling the music on causes a slowdown of around 2 orders of magnitude. Asynchronous MIDI cannot be used due to a bug in Mars audio rendering
- Too many hue or brightness shifts in either direction (more than 10) could be irreversible as the hue and brightness coefficients approach and eventually reach 0
- Superzooms that you can find on YouTube are not possible in this plotter. They typically use BigDouble and other high-level abstractions to be able to plot deeper down into the fractal