HuarongDao Inspired Block Game

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1 Introduction

In our final project for the Embedded System course, our group created a block-moving game on a DE1-SoC board using Logitech F310 gamepad as controlling inputs, as well as a VGA display to show our game graphics and speakers to play a background soundtrack along the game playing experience. The simple logic of this game is inspired by both HuarongDao and some other block-moving games. As the player, he/she will be displayed with a 4x4 game space with 15 numbered (1-15) blocks. And the numbers will have scrambled placements on the space. The task for the player is, by moving one block at a time, to re-order the blocks into the correct numerical order.

For displaying the graphic on the VGA screen, we implemented a hardware system verilog design to register each game block as a hardware component, in which each block will be displayed on the screen based on the location information stored in memory. Also, the background soundtrack is implemented in System Verilog completely, players will hear the soundtrack the moment they start the game.

Other than those hardware designs, the rest of the system is handled by software in C. First, the Logitech F310 gamepad was connected and registered as a USB HID device using the usblib 1.0 library. After interpreting the packets from Direct-Input mode from the gamepad, we were able to control the game logic using the gamepad. Additionally, the game logic is fully in C code. It will accept input from the gamepad and change the hardware components. Lastly, we also have a C file in charge of any controlling action on the game blocks.
In this report, we will first cover the system Architecture overview to give the whole system design a review. Then, we will cover the hardware design on both the VGA display and soundtrack. Next, we will cover the software design in our design, which will be on both the control drivers and game logic. We will then show a series of screenshots of our project. All the designs and code will be included in the Code Appendix for viewing. Additionally, you can download the zip files in (GitHub link) to try to load this design.

2 System Overview
3 Hardware

Hardware Interface

**Writedata:** 32-bit data received from software

**Address:** determines the locations the writedata need to be stored to

Signal x, y control the location of corresponding blocks.

Cursor_x, cursor_y control the location of the cursor.

Signal selected indicate whether the block at current cursor is selected.

Signal win decides whether to display the smile face.

<table>
<thead>
<tr>
<th>Address</th>
<th>Writedata (4 bits per cell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x1</td>
</tr>
<tr>
<td>1</td>
<td>x5</td>
</tr>
<tr>
<td>2</td>
<td>x9</td>
</tr>
<tr>
<td>3</td>
<td>x13</td>
</tr>
</tbody>
</table>
VGA Display

Digital numbers are simple, so we hard coded the pixel configuration of every number in the hardware. The black box represents the cursor. Similar to digital numbers, its pixel configuration was also hard coded in hardware. The smile face is a 240x240 px image, which is loaded into memory during the initialization process. One pixel is read from memory every cycle.

**Soundtrack playing**

For the audio part, we used an Audio Controller module, which can accept Clock, left/right channel input, and allow_input signals. The tune of the sound is controlled by changing the frequency of input. The frequency number sequences is the data of music which is stored in 2 M10K memory modules as 2 different music selections. When the music is playing, a slower counter advances the memory address and sends the frequency control data to the audio controller.
In this section, we will discuss the software design of this project. It will cover the game logic design, hardware interaction, and gamepad driver.

**GameLogic**
In the `gamelogic.c` file, this is the file containing all of our game logic for this project. This is our core program that will take in gamepad input and update the VGA display based on the game states. The main states our program keeps track of are:

- **Game states**
  - Blocks location (in the 4x4 grid)
  - Steps remaining
  - Win
- **Cursor location**
  - Cursor x/y (in the 4x4 grid)
- **Gamepad inputs**
  - Actions from player (up/down/left/right, select/un-select)

**Game States:** For the game state, it will record all the needed information about each block state in the game, which can be used to communicate with the hardware to determine the location of each displayed VGA block. When starting the game, it will initialize a 4x4 board with a random order of 15 blocks and 1 empty block. In the struct for the game state, it will record this information about each block and its relative location in the 4x4 grid.

**Code for customized Struct for our gamelogic**

```c
typedef struct {
    unsigned char x;
    unsigned char y;
} location_t;

typedef struct {
    unsigned char block_id;
    int type; // 0: Empty, 1: Normal Block, 2: Target Block
    location_t location;
} block_t;

typedef struct {
    location_t cursor_loc;
    location_t selected; // set to 4,4 if none gets selected
    unsigned char win;
    block_t blocks[15];
```
Code for Gamelogic Array

```c
block_t arr[4][4] = {
    {block1, block2, block3, block4},
    {block5, block6, block7, block8},
    {block9, block10, block11, block12},
    {block13, block14, block15, block0}};
for (int i = 0; i < 4; i++)
    {
        for (int j = 0; j < 4; j++)
            {
                arr[i][j].location.x = j;
                arr[i][j].location.y = i;
            }
    }
```

**Cursor Locations:** Additionally, we also record the player’s cursor location in the game, which reflects which block they are currently on. The cursor will also have a visual effect on the display, which will use information from this code.

**Gamepad Inputs:** Based on the intercepted packets from the gamepad driver, the game logic file will use the input to change game states, which will reflect on the VGA display if the state changes.

**Code for gamepad driver in gamelogic.c file**

```c
int r = libusb_interrupt_transfer(gamepad, endpoint_address, data, sizeof(data),
actual_length, 0);
if (r == 0 && actual_length == sizeof(data))
    {
        // code for intercepting gamepad input and conduct game logic
    }
```

With the game logic file recording the game states and communicating them with the hardware, the player can do the following actions in our project game:

1. Connect the gamepad to the FPGA board and start the game
2. Start the game with random order of the blocks
3. Move the cursor to select the block to interact with
4. Press A to select the current block
5. Move blocks (with empty space nearby) with gamepad input
6. Press A again to deselect from the current block
7. Repeat steps 3-6 till
8. Win: blocks are sorted in order
9. Reset: Press Y to reset the game

**Gamepad Driver**

The main peripheral of this project is a Logitech F310 Gamepad, which is used to provide a way for the player to interact with the game through controller pressing. For connecting the gamepad with our program, we use libusb 1.0 to identify the gamepad as a USB HID device, and we will use the intercepted packets as user input actions.

While implementing the driver for the gamepad, there were some roadblocks we had to overcome to make sure the controller was usable:

1. The controller (Logitech F310) has two different modes when plugging into the board, X-Input, and Direct-Input. According to the analysis using WireShark, those two modes can send different styles of packets to the board. After researching what kind of input will be best suited for FPGA board connection, we found out, by using Direct-Input mode, the board can identify the gamepad as a USB device, which is less raw to handle.
2. Although as a USB device, it is not the keyboard type we used to use in our lab implementation. Therefore, we need to find out the correct way to connect the gamepad and receive its packets. After looking into the documentation of libusb1.0, we found out there is a `USB_HID_GAMEPAD_PROTOCOL` we can use to do the above works.
3. After that, the input from the gamepad is in its raw format of data. We need to find useful data from the raw packets that represent certain actions on the gamepad. Also, we need to understand how the gamepad sends packets. After connecting the gamepad to a test driver, we were successfully able to find the correct data to use in the game logic file to represent the actions on the gamepad.
for (d = 0; d < num_devs; d++) {
    libusb_device *dev = devs[d];
    if (libusb_get_device_descriptor(dev, &desc) < 0) {
        fprintf(stderr, "Error: libusb_get_device_descriptor failed\n");
        exit(1);
    }

    if (desc.idVendor == LOGITECH_VENDOR_ID && desc.idProduct ==
        LOGITECH_F310_PRODUCT_ID) {
        struct libusb_config_descriptor *config;
        libusb_get_config_descriptor(dev, 0, &config);
        for (i = 0; i < config->bNumInterfaces; i++) {
            for (k = 0; k < config->interface[i].num_altsetting; k++) {
                const struct libusb_interface_descriptor *inter =
                config->interface[i].altsetting + k;
                if (inter->bInterfaceClass == USB_HID_INTERFACE_CLASS &&
                    inter->bInterfaceProtocol == USB_HID_GAMEPAD_PROTOCOL) {
                    int r;
                    if ((r = libusb_open(dev, &gamepad)) != 0) {
                        fprintf(stderr, "Error: libusb_open failed: %d\n", r);
                        exit(1);
                    }
                    if (libusb_kernel_driver_active(gamepad, i))
                        libusb_detach_kernel_driver(gamepad, i);
                    libusb_set_auto_detach_kernel_driver(gamepad, 1);
                    if ((r = libusb_claim_interface(gamepad, i)) != 0) {
                        fprintf(stderr, "Error: libusb_claim_interface failed:
%d\n", r);
                        exit(1);
                    }
                    *endpoint_address = inter->endpoint[0].bEndpointAddress;
                    goto found;
                }
            }
        }
    }
}
After setup, we only used partial input from the gamepad, which is enough for our game logic implementation:

- Arrow buttons: Up/Down/Left/Right for moving the cursor/block
- Action buttons: A/Y for different game interaction

Note: in the game logic file, the game loop will ignore any other packet input that is not one of the above actions.

**vga_ball.c**

This file helps to aid the interface between hardware components with our software design. The main purpose of this file gives the necessary communication methods for software in C to access hardware information on our game blocks.

**Code for VLA struct**

```c
typedef struct {
    location_t cursor_loc;
    location_t selected; // set to 4,4 if none gets selected
    unsigned char win;
    block_t blocks[15];
} vga_ball_arg_t;

struct vga_ball_dev {
    struct resource res; /* Resource: our registers */
    void __iomem *virtbase; /* Where registers can be accessed in memory */
    location_t locations[16];
} dev;

static void writelocation(location_t loc1, location_t loc2,
                           location_t loc3, location_t loc4,
                           unsigned char offset)
{
    unsigned long data;
    data = (((loc1.x << 28) & 0xF0000000) | ((loc1.y << 24) & 0x0F000000) |
            ((loc2.x << 20) & 0x0F000000) | ((loc2.y << 16) & 0x000F0000) |
            ((loc3.x << 12) & 0x0000F000) | ((loc3.y << 8) & 0x00000F00))
            /* Other locations */
    /* Write data to registers */
}
```
5 Discussion and Learning

In our project design, we implemented a essentially solve-15 game in a FPGA board situation. The design was simple, but we were able to combine things we learned from classes and labs into this project.

The roadblock encountered in this project was also able to help us understand the design in embedded systems further.

- First, connecting a USB gamepad requires finding the compatible controller to the FPGA board, as well as finding the correct lib to use so the board can identify the USB plugin as a HID device. Also, since most online resources on libusb 1.0 are about how to use it for keyboard input, we need to deal with the raw packets from the gamepad ourselves. After using WireShark to analyze the output, we were able to find the data we needed to use for our gamelogic.

- Second, since our project requires the display of pictures and numerical data, we need to find a way to load our resources into the hardware for compiling. The way we came up with were two parts: for the block number, we wrote the correct display of each number (1-15) in our systemverilog file; then, for the picture we need to display, we use tool to transfer the 240x240 png file into .mif file, which can be latter used to create new memory black in Quartus.

- Third, for the gamelogic implementation, we need to understand how can we interface with the block components in hardware. The method we came up with was to pass the gamestate to the block driver file, and in the driver, it will break down the gamestate into addresses to retrieve/update. Thus, our graphic display was able to show on VGA based on the current gamestate. By restricting the player actions inside the gamelogic, we were able to avoid any hardware faults.

There are also many future improvements we can do to make this a better game to play with:
- The game interface is still in a rough shape since we did not use Sprite to display layers of graphics. If time allowed, we could make a more sophisticated game UI so the playing will be smooth.
- The soundtrack playing is currently isolated from the game playing, our hardware was capable to play the sound, all we need to add was another sound driver file. By doing so, we can add more game sound to the project.
- For the block display, we displayed everything on a single layer. Since our gamelogic is simple enough, there seems to have no bug/lag due to memory accessing issue. However, for future more complicated UI design, we need to make sure our memory access has no conflict.

6 Team Contribution

- Haobo Liu (hl3645): Gamelogic design and implementation, Project documentation writing (slides, reports)
- Nina Hsu (hh2961): GameLogic design and implementation
- Jingwei Zhang (jz3555): Soundtrack playing design, graphic display implementation
- Jiusheng Zhang (jz3444): Soundtrack playing design, graphic display implementation
- Rui Chu (rc3414): Gamelogic design and implementation, graphic display implementation
SV file:
Music.v

// megafuction wizard: %RAM: 1-PORT%
// GENERATION: STANDARD
// VERSION: WM1.0
// MODULE: altsyncram

// File Name: music.v
// Megafunction Name(s):
// altsyncram
//
// Simulation Library Files(s):
// altera_mf

// THIS IS A WIZARD-GENERATED FILE. DO NOT EDIT THIS FILE!

// 22.1std.1 Build 917 02/14/2023 SC Lite Edition

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// synopsys translate_off
`timescale 1 ps / 1 ps
// synopsys translate_on
module music (address, clock, data, wren, q);

    input [6:0] address;
    input clock;
    input [7:0] data;
    input wren;
    output [7:0] q;
`ifndef ALTERA_RESERVED_QIS
// synopsys translate_off
`endif
    tri1 clock;
`ifndef ALTERA_RESERVED_QIS
// synopsys translate_on
`endif

    wire [7:0] sub_wire0;
    wire [7:0] q = sub_wire0[7:0];

    altsyncram altsyncram_component ( //
        .address_a (address),
        .clock0 (clock),
        .data_a (data),
        .wren_a (wren),
        .q_a (sub_wire0),
        .aclr0 (1'b0),
        .aclrl (1'b0),
        .address_b (1'b1),
        .addressstall_a (1'b0),
        .addressstall_b (1'b0),
        .byteena_a (1'b1),
        .byteena_b (1'b1),
        .clock1 (1'b1),
        .clocken0 (1'b1),
        .clocken1 (1'b1),
.clocken2 (1'b1),
.clocken3 (1'b1),
data_b (1'b1),
eccstatus (),
.q_b (),
rden_a (1'b1),
rden_b (1'b1),
wren_b (1'b0));
defparam altsyncram_component.clock_enable_input_a = "BYPASS",
    altsyncram_component.clock_enable_output_a = "BYPASS",
    altsyncram_component.init_file = "../music.mif",
    altsyncram_component.intended_device_family = "Cyclone V",
    altsyncram_component.lpm_hint = "ENABLE_RUNTIME_MOD=NO",
    altsyncram_component.lpm_type = "altsyncram",
    altsyncram_component.numwords_a = 128,
    altsyncram_component.operation_mode = "SINGLE_PORT",
    altsyncram_component.outdata_aclr_a = "NONE",
    altsyncram_component.outdata_reg_a = "CLOCK0",
    altsyncram_component.power_up_uninitialized = "FALSE",
    altsyncram_component.ram_block_type = "M10K",
    altsyncram_component.read_during_write_mode_port_a = "DONT_CARE",
    altsyncram_component.widthad_a = 7,
    altsyncram_component.width_a = 8,
    altsyncram_component.width_byteena_a = 1;
endmodule

// =============================================================
// CNX file retrieval info
// =============================================================
// Retrieval info: PRIVATE: ADDRESSSTALL_A NUMERIC "0"
// Retrieval info: PRIVATE: AclrAddr NUMERIC "0"
// Retrieval info: PRIVATE: AclrByte NUMERIC "0"
// Retrieval info: PRIVATE: AclrData NUMERIC "0"
// Retrieval info: PRIVATE: AclrOutput NUMERIC "0"
// Retrieval info: PRIVATE: BYTE_ENABLE NUMERIC "0"
// Retrieval info: PRIVATE: BYTE_SIZE NUMERIC "8"
// Retrieval info: PRIVATE: BlankMemory NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_INPUT_A NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_OUTPUT_A NUMERIC "0"
// functions, and any output files from any of the foregoing
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// synopsys translate_off
`timescale 1 ps / 1 ps
// synopsys translate_on
module face ( 
  address,
  clock,
  q);

  input [15:0] address;
  input    clock;
  output   [2:0] q;
`ifndef ALTERA_RESERVED_QIS
// synopsys translate_off
`endif
  tri    clock;
`ifndef ALTERA_RESERVED_QIS
// synopsys translate_on
`endif

  wire  [2:0] sub_wire0;
  wire  [2:0] q = sub_wire0[2:0];

  altsyncram altsyncram_component ( 
    .address_a (address),
    .clock0 (clock),
    .q_a (sub_wire0),
    .aclr0 (1'b0),
    .aclrl (1'b0),
    .address_b (1'b1),
    .q (q)),
.addressstall_a (1'b0),
.addressstall_b (1'b0),
.byteena_a (1'b1),
.byteena_b (1'b1),
.clock1 (1'b1),
.clocken0 (1'b1),
.clocken1 (1'b1),
.clocken2 (1'b1),
.clocken3 (1'b1),
data_a (3(1'b1)),
.data_b (1'b1),
.eccstatus (),
.q_b (),
rden_a (1'b1),
rden_b (1'b1),
wren_a (1'b0),
wren_b (1'b0));
defparam
  altsyncram_component.address_aclr_a = "NONE",
  altsyncram_component.clock_enable_input_a = "BYPASS",
  altsyncram_component.clock_enable_output_a = "BYPASS",
  altsyncram_component.init_file = "face.mif",
  altsyncram_component.intended_device_family = "Cyclone V",
  altsyncram_component.lpm_hint = "ENABLE_RUNTIME_MOD=NO",
  altsyncram_component.lpm_type = "altsyncram",
  altsyncram_component.numwords_a = 57600,
  altsyncram_component.operation_mode = "ROM",
  altsyncram_component.outdata_aclr_a = "NONE",
  altsyncram_component.outdata_reg_a = "CLOCK0",
  altsyncram_component.ram_block_type = "M10K",
  altsyncram_component.widthhad_a = 16,
  altsyncram_component.width_a = 3,
  altsyncram_component.width_byteena_a = 1;
endmodule

// ==============================================================
// CNX file retrieval info
// ==============================================================
// Retrieval info: PRIVATE: ADDRESSSTALL_A NUMERIC "0"
// Retrieval info: PRIVATE: AclrAddr NUMERIC "0"
PRIVATE: AclrByte NUMERIC "0"
PRIVATE: AclrOutput NUMERIC "0"
PRIVATE: BYTE_ENABLE NUMERIC "0"
PRIVATE: BYTE_SIZE NUMERIC "8"
PRIVATE: BlankMemory NUMERIC "0"
PRIVATE: CLOCK_ENABLE_INPUT_A NUMERIC "0"
PRIVATE: CLOCK_ENABLE_OUTPUT_A NUMERIC "0"
PRIVATE: Clken NUMERIC "0"
PRIVATE: IMPLEMENT_IN_LES NUMERIC "0"
PRIVATE: INIT_FILE_LAYOUT STRING "PORT_A"
PRIVATE: INIT_TO_SIM_X NUMERIC "0"
PRIVATE: INTENDED_DEVICE_FAMILY STRING "Cyclone V"
PRIVATE: JTAG_ENABLED NUMERIC "0"
PRIVATE: JTAG_ID STRING "NONE"
PRIVATE: MAXIMUM_DEPTH NUMERIC "0"
PRIVATE: MIFFilename STRING "face.mif"
PRIVATE: NUMWORDS_A NUMERIC "57600"
PRIVATE: RAM_BLOCK_TYPE NUMERIC "2"
PRIVATE: RegAddr NUMERIC "1"
PRIVATE: RegOutput NUMERIC "1"
PRIVATE: SYNTH_WRAPPER_GEN_POSTFIX STRING "0"
PRIVATE: SingleClock NUMERIC "1"
PRIVATE: UseDQRAM NUMERIC "0"
PRIVATE: WidthAddr NUMERIC "16"
PRIVATE: WidthData NUMERIC "3"
PRIVATE: rden NUMERIC "0"
LIBRARY: altera_mf altera_mf.altera_mf_components.all
CONSTANT: ADDRESS_ACLR_A STRING "NONE"
CONSTANT: CLOCK_ENABLE_INPUT_A STRING "BYPASS"
CONSTANT: CLOCK_ENABLE_OUTPUT_A STRING "BYPASS"
CONSTANT: INIT_FILE STRING "face.mif"
CONSTANT: INTENDED_DEVICE_FAMILY STRING "Cyclone V"
CONSTANT: LPM_HINT STRING "ENABLE_RUNTIME_MOD=NO"
CONSTANT: LPM_TYPE STRING "altsyncram"
CONSTANT: NUMWORDS_A NUMERIC "57600"
CONSTANT: OPERATION_MODE STRING "ROM"
CONSTANT: OUTDATA_ACLR_A STRING "NONE"
CONSTANT: OUTDATA_REG_A STRING "CLOCK0"
CONSTANT: RAM_BLOCK_TYPE STRING "M10K"
CONSTANT: WIDTHADDR_A NUMERIC "16"
CONSTANT: WIDTH_A NUMERIC "3"
CONSTANT: WIDTH_BYTEENA_A NUMERIC "1"
Vga_ball.sv

/*
* Avalon memory-mapped peripheral that generates VGA
*
* Stephen A. Edwards
* Columbia University
*/

module vga_ball(input logic clk,
    input logic reset,
    input logic [31:0] writedata,
    input logic write,
    input chipselect,
    input logic [4:0] address,

    output logic [7:0] VGA_R, VGA_G, VGA_B,
    output logic VGA_CLK, VGA_HS, VGA_VS,
    VGA_BLANK_n,
    output logic VGA_SYNC_n);

logic [10:0] hcount;
logic [9:0] vcount;

logic [7:0] background_r, background_g, background_b;

logic [9:0] x1, y1;
```vhdl
logic [9:0] x2, y2;
logic [9:0] x3, y3;
logic [9:0] x4, y4;
logic [9:0] x5, y5;
logic [9:0] x6, y6;
logic [9:0] x7, y7;
logic [9:0] x8, y8;
logic [9:0] x9, y9;
logic [9:0] x10, y10;
logic [9:0] x11, y11;
logic [9:0] x12, y12;
logic [9:0] x13, y13;
logic [9:0] x14, y14;
logic [9:0] x15, y15;
logic [9:0] cursor_x, cursor_y;
logic [9:0] width;
logic [9:0] selected_x, selected_y;
logic win;

vga_counters counters (.clk50(clk), .*);
logic [23:0] face_out;

design face f1(hcount[10:1] - 119 + (vcount - 119) * 240, clk, face_out);

always_ff @(posedge clk)
  if (reset) begin
    width = 10'h5;
    background_r <= 8'h0;
    background_g <= 8'h0;
    background_b <= 8'h0;
    x1 <= 10'h0;
    y1 <= 10'h0;
    x2 <= 10'h78; // 120
    y2 <= 10'h0;
    x3 <= 10'hf0; // 240
    y3 <= 10'h0;
    x4 <= 10'h0;
    y4 <= 10'h78; // 120
    x5 <= 10'h78;
    y5 <= 10'h78;
    x6 <= 10'hf0;
    y6 <= 10'h78;
    x7 <= 10'h168; // 360
    y7 <= 10'h78;
  end
endmodule
```
x8 <= 10'h0;
y8 <= 10'hf0;
x9 <= 10'h78;
y9 <= 10'hf0;
x10 <= 10'hf0;
y10 <= 10'hf0;
x11 <= 'h168;
y11 <= 'h168;
x12 <= 10'h00;
y12 <= 10'h168;
x13 <= 10'h78;
y13 <= 10'h168;
x14 <= 10'hf0;
y14 <= 10'h168;
x15 <= 10'h168;
y15 <= 10'h168;
cursor_x <= 10'h0;
cursor_y <= 10'h0;
selected_x = 10'h4;
selected_y = 10'h4;
win <= 1'b0;
  end else if (chipselect && write)
    case (address)
      5'h00 : begin
        x1 <= {1'b0, writedata[31:28] * 120};
y1 <= {1'b0, writedata[27:24] * 120};
x2 <= {1'b0, writedata[23:20] * 120};
y2 <= {1'b0, writedata[19:16] * 120};
x3 <= {1'b0, writedata[15:12] * 120};
y3 <= {1'b0, writedata[11:8] * 120};
x4 <= {1'b0, writedata[7:4] * 120};
y4 <= {1'b0, writedata[3:0] * 120};
      end
      5'h01 : begin
        x5 <= {1'b0, writedata[31:28] * 120};
y5 <= {1'b0, writedata[27:24] * 120};
x6 <= {1'b0, writedata[23:20] * 120};
y6 <= {1'b0, writedata[19:16] * 120};
x7 <= {1'b0, writedata[15:12] * 120};
y7 <= {1'b0, writedata[11:8] * 120};
x8 <= {1'b0, writedata[7:4] * 120};
     end
end
y8 <= {1'b0, writedata[3:0] * 120};
end
5'h02 : begin
x9 <= {1'b0, writedata[31:28] * 120};
y9 <= {1'b0, writedata[27:24] * 120};
x10 <= {1'b0, writedata[23:20] * 120};
y10 <= {1'b0, writedata[19:16] * 120};
x11 <= {1'b0, writedata[15:12] * 120};
y11 <= {1'b0, writedata[11:8] * 120};
x12 <= {1'b0, writedata[7:4] * 120};
y12 <= {1'b0, writedata[3:0] * 120};
end
3'h03 : begin
x13 <= {1'b0, writedata[31:28] * 120};
y13 <= {1'b0, writedata[27:24] * 120};
x14 <= {1'b0, writedata[23:20] * 120};
y14 <= {1'b0, writedata[19:16] * 120};
x15 <= {1'b0, writedata[15:12] * 120};
y15 <= {1'b0, writedata[11:8] * 120};
cursor_x <= {1'b0, writedata[7:4] * 120};
cursor_y <= {1'b0, writedata[3:0] * 120};
end
3'h04 : begin
selected_x <= {1'b0, writedata[15:12]};
selected_y <= {1'b0, writedata[11:8]};
win <= writedata[0];
end
endcase
always_comb begin
  {VGA_R, VGA_G, VGA_B} = (8’h0, 8’h0, 8’h0);
  if (VGA_BLANK_n)
    if (hcount[10:1] >= 0 \&\& hcount[10:1] < 480) begin
      if (hcount[10:1] >= x1 + 71 \&\& hcount[10:1] < x1 + 71 + width \&\& vcount >= y1 + 35 \&\& vcount < y1 + 83 + width \| \| 1
        hcount[10:1] >= x2 + 47 \&\& hcount[10:1] < x2 + 71 + width \&\& (vcount >= y2 + 35 \&\& vcount < y2 + 35 + width \|)
      vcount >= y2 + 59 \&\& vcount < y2 + 59 + width \|)
      vcount >= y2 + 83 \&\& vcount < y2 + 83 + width) \|)
      hcount[10:1] >= x2 + 71 \&\& hcount[10:1] < x2 + 71 + width \&\& vcount >= y2 + 35 \&\& vcount < y2 + 59 + width\|}
\texttt{hcount[10:1] >= x2 + 47 \&\& hcount[10:1] < x2 + 47 + width \&\& vcount >= y2 + 59}
\texttt{\&\& vcount < y2 + 83 + width} // 2
\texttt{hcount[10:1] >= x3 + 47 \&\& hcount[10:1] < x3 + 71 + width \&\& (vcount >= y3 + 35 \&\& vcount < y3 + 35 + width} ||
\texttt{vcount >= y3 + 59 \&\& vcount < y3 + 59 + width} ||
\texttt{vcount >= y3 + 83 \&\& vcount < y3 + 83 + width) ||}
\texttt{hcount[10:1] >= x3 + 71 \&\& hcount[10:1] < x3 + 71 + width \&\& vcount >= y3 + 35}
\texttt{\&\& vcount < y3 + 83 + width} // 3
\texttt{hcount[10:1] >= x4 + 47 \&\& hcount[10:1] < x4 + 71 + width \&\& vcount >= y4 + 59}
\texttt{\&\& vcount < y4 + 59 + width} ||
\texttt{hcount[10:1] >= x4 + 47 \&\& hcount[10:1] < x4 + 47 + width \&\& vcount >= y4 + 35}
\texttt{\&\& vcount < y4 + 59 + width} ||
\texttt{hcount[10:1] >= x4 + 71 \&\& hcount[10:1] < x4 + 71 + width \&\& vcount >= y4 + 35}
\texttt{\&\& vcount < y4 + 83 + width} // 4
\texttt{hcount[10:1] >= x5 + 47 \&\& hcount[10:1] < x5 + 71 + width \&\& (vcount >= y5 + 35 \&\& vcount < y5 + 35 + width} ||
\texttt{vcount >= y5 + 59 \&\& vcount < y5 + 59 + width} ||
\texttt{vcount >= y5 + 83 \&\& vcount < y5 + 83 + width) ||}
\texttt{hcount[10:1] >= x5 + 71 \&\& hcount[10:1] < x5 + 71 + width \&\& vcount >= y5 + 59}
\texttt{\&\& vcount < y5 + 83 + width} ||
\texttt{hcount[10:1] >= x5 + 47 \&\& hcount[10:1] < x5 + 47 + width \&\& vcount >= y5 + 35}
\texttt{\&\& vcount < y5 + 59 + width} ||
\texttt{hcount[10:1] >= x6 + 47 \&\& hcount[10:1] < x6 + 71 + width \&\& (vcount >= y6 + 35 \&\& vcount < y6 + 35 + width} ||
\texttt{vcount >= y6 + 59 \&\& vcount < y6 + 59 + width} ||
\texttt{vcount >= y6 + 83 \&\& vcount < y6 + 83 + width) ||}
\texttt{hcount[10:1] >= x6 + 71 \&\& hcount[10:1] < x6 + 71 + width \&\& vcount >= y6 + 59}
\texttt{\&\& vcount < y6 + 83 + width} ||
\texttt{hcount[10:1] >= x6 + 47 \&\& hcount[10:1] < x6 + 47 + width \&\& vcount >= y6 + 35}
\texttt{\&\& vcount < y6 + 83 + width} ||
\texttt{hcount[10:1] >= x6 + 71 \&\& hcount[10:1] < x6 + 71 + width \&\& vcount >= y6 + 35}
\texttt{\&\& vcount < y7 + 35 + width} ||
\texttt{hcount[10:1] >= x7 + 47 \&\& hcount[10:1] < x7 + 71 + width \&\& vcount >= y7 + 35}
\texttt{\&\& vcount < y7 + 83 + width} ||
\texttt{hcount[10:1] >= x7 + 71 \&\& hcount[10:1] < x7 + 71 + width \&\& vcount >= y7 + 35}
\texttt{\&\& vcount < y7 + 83 + width} ||
\texttt{hcount[10:1] >= x8 + 47 \&\& hcount[10:1] < x8 + 71 \&\& (vcount >= y8 + 35 \&\& vcount < y8 + 35 + width} ||
\texttt{vcount >= y8 + 59 \&\& vcount < y8 + 59 + width} ||
\texttt{vcount >= y8 + 83 \&\& vcount < y8 + 83 + width) ||}
\texttt{hcount[10:1] >= x8 + 47 \&\& hcount[10:1] < x8 + 47 + width \&\& vcount >= y8 + 35}
\texttt{\&\& vcount < y8 + 83 + width} ||
\texttt{hcount[10:1] >= x8 + 71 \&\& hcount[10:1] < x8 + 71 + width \&\& vcount >= y8 + 35}
\texttt{\&\& vcount < y8 + 83 + width} ||
\texttt{hcount[10:1] >= x8 + 71 \&\& hcount[10:1] < x8 + 71 + width \&\& vcount >= y8 + 35}
\hspace{1cm} hcount[10:1] >= x9 + 47 \&\& hcount[10:1] < x9 + 71 + width \\
\hspace{1cm} (vcount >= y9 + 35 \&\& vcount < y9 + 35 + width ||
\hspace{1cm} vcount >= y9 + 59 \&\& vcount < y9 + 59 + width ||
\hspace{1cm} vcount >= y9 + 83 \&\& vcount < y9 + 83 + width) ||
\hspace{1cm} hcount[10:1] >= x9 + 47 \&\& hcount[10:1] < x9 + 47 + width \&\& vcount >= y9 + 35
\hspace{1cm} \&\& vcount < y9 + 59 + width ||
\hspace{1cm} hcount[10:1] >= x9 + 71 \&\& hcount[10:1] < x9 + 71 + width \&\& vcount >= y9 + 35
\hspace{1cm} \&\& vcount < y9 + 83 + width || // 9
\hspace{1cm} hcount[10:1] >= x10 + 47 \&\& hcount[10:1] < x10 + 47 + width \&\& vcount >= y10 + 35 \&\& vcount < y10 + 83 + width ||
\hspace{1cm} hcount[10:1] >= x10 + 71 \&\& hcount[10:1] < x10 + 95 + width \&\&
\hspace{1cm} (vcount >= y10 + 35 \&\& vcount < y10 + 35 + width ||
\hspace{1cm} vcount >= y10 + 83 \&\& vcount < y10 + 83 + width) ||
\hspace{1cm} hcount[10:1] >= x10 + 71 \&\& hcount[10:1] < x10 + 71 + width \&\& vcount >= y10 + 35 \&\& vcount < y10 + 83 + width ||
\hspace{1cm} hcount[10:1] >= x10 + 95 \&\& hcount[10:1] < x10 + 95 + width \&\& vcount >= y10 + 35 \&\& vcount < y10 + 83 + width || // 10
\hspace{1cm} hcount[10:1] >= x11 + 47 \&\& hcount[10:1] < x11 + 47 + width \&\& vcount >= y11 + 35 \&\& vcount < y11 + 83 + width ||
\hspace{1cm} hcount[10:1] >= x11 + 95 \&\& hcount[10:1] < x11 + 95 + width \&\& vcount >= y11 + 35 \&\& vcount < y11 + 83 + width || // 11
\hspace{1cm} hcount[10:1] >= x12 + 47 \&\& hcount[10:1] < x12 + 47 + width \&\& vcount >= y12 + 35 \&\& vcount < y12 + 83 + width ||
\hspace{1cm} hcount[10:1] >= x12 + 71 \&\& hcount[10:1] < x12 + 95 + width \&\&
\hspace{1cm} (vcount >= y12 + 35 \&\& vcount < y12 + 35 + width ||
\hspace{1cm} vcount >= y12 + 59 \&\& vcount < y12 + 59 + width ||
\hspace{1cm} vcount >= y12 + 83 \&\& vcount < y12 + 83 + width) ||
\hspace{1cm} hcount[10:1] >= x12 + 95 \&\& hcount[10:1] < x12 + 95 + width \&\& vcount >= y12 + 35 \&\& vcount < y12 + 59 + width ||
\hspace{1cm} hcount[10:1] >= x12 + 71 \&\& hcount[10:1] < x12 + 71 + width \&\& vcount >= y12 + 59 \&\& vcount < y12 + 83 + width || // 12
\hspace{1cm} hcount[10:1] >= x13 + 47 \&\& hcount[10:1] < x13 + 47 + width \&\& vcount >= y13 + 35 \&\& vcount < y13 + 83 + width ||
\hspace{1cm} hcount[10:1] >= x13 + 71 \&\& hcount[10:1] < x13 + 95 \&\&
\hspace{1cm} (vcount >= y13 + 35 \&\& vcount < y13 + 35 + width ||
\hspace{1cm} vcount >= y13 + 59 \&\& vcount < y13 + 59 + width ||
\hspace{1cm} vcount >= y13 + 83 \&\& vcount < y13 + 83 + width) ||
\hspace{1cm} hcount[10:1] >= x13 + 95 \&\& hcount[10:1] < x13 + 95 + width \&\& vcount >= y13 + 35 \&\& vcount < y13 + 83 + width || // 13
\hspace{1cm} hcount[10:1] >= x14 + 47 \&\& hcount[10:1] < x14 + 47 + width \&\& vcount >= y14 + 35 \&\& vcount < y14 + 83 + width ||
if (hcount[10:1] >= cursor_x + 5 \&\& hcount[10:1] < cursor_x + 115 \&\& vcount >= cursor_y + 5 \&\& vcount < cursor_y + 7) {
    (VGA_R, VGA_G, VGA_B) = (8'h0, 8'h0, 8'h0);
    if (hcount[10:1] >= cursor_x + 5 \&\& hcount[10:1] < cursor_x + 7 \&\& vcount >= cursor_y + 5 \&\& vcount < cursor_y + 115) {
        (VGA_R, VGA_G, VGA_B) = (8'h0, 8'h0, 8'h0);
        if (hcount[10:1] >= cursor_x + 113 \&\& hcount[10:1] < cursor_x + 115 \&\& vcount >= cursor_y + 113 \&\& vcount < cursor_y + 115) {
            (VGA_R, VGA_G, VGA_B) = (8'h0, 8'h0, 8'h0);
        }
    }
}

if (selected_x < 4 \&\& selected_y < 4) begin

hcount[10:1] >= cursor_x + 5 \&\& hcount[10:1] < cursor_x + 95 \&\& vcount >= cursor_y + 59 \&\& vcount < cursor_y + 95 + width ||

hcount[10:1] >= cursor_x + 95 \&\& hcount[10:1] < cursor_x + 95 + width \&\& vcount >= cursor_y + 95 + width ||

hcount[10:1] >= cursor_y + 115 \&\& vcount >= cursor_y + 95 || if (hcount[10:1] % 119 == 0 || vcount % 119 == 0)

(VGA_R, VGA_G, VGA_B) = (8'h00, 8'h80, 8'h80);

else

(VGA_R, VGA_G, VGA_B) = (8'hbf, 8'h8f, 8'h00);

end

else

(VGA_R, VGA_G, VGA_B) = (background_r, background_g, background_b);

/* cursor */

if (hcount[10:1] >= cursor_x + 5 \&\& hcount[10:1] < cursor_x + 115 \&\& vcount >= cursor_y + 5 \&\& vcount < cursor_y + 115) {
    (VGA_R, VGA_G, VGA_B) = (background_r, background_g, background_b);

}
if (hcount[10:1] >= cursor_y + 7 && vcount >= cursor_y + 9)
    {VGA_R, VGA_G, VGA_B} = (8'hff, 8'hff, 8'h00);
if (hcount[10:1] >= cursor_y + 7 && vcount < cursor_y + 9)
    {VGA_R, VGA_G, VGA_B} = (8'hff, 8'hff, 8'h00);
if (hcount[10:1] < cursor_y + 113 && vcount >= cursor_y + 7 && vcount < cursor_y + 113)
    {VGA_R, VGA_G, VGA_B} = (8'hff, 8'hff, 8'h00);
end

if (win == 1) begin
    if (hcount[10:1] == 119 && vcount == 359 && vcount >= 119 && vcount < 359)
        begin
            {VGA_R, VGA_G, VGA_B} = face_out;
            /*
            if (face_out[2] == 1)
                VGA_R <= 8'hff;
            else
                VGA_R <= 8'h00;
            if (face_out[1] == 1)
                VGA_G <= 8'hff;
            else
                VGA_G <= 8'h00;
            if (face_out[0] == 1)
                VGA_B <= 8'hff;
            else
                VGA_B <= 8'h00;
            */
        end
end
end

endmodule

module vga_counters(
    input logic clk50, reset,
    output logic [10:0] hcount, // hcount[10:1] is pixel column
    output logic [9:0] vcount, // vcount[9:0] is pixel row
    output logic VGA_CLK, VGA_HS, VGA_VS, VGA_BLANK_n, VGA_SYNC_n);
/ * 640 X 480 VGA timing for a 50 MHz clock: one pixel every other cycle *
* HCOUNT 1599 0       1279       1599 0
* _____________________________
* _________|      Video      |___________|      Video
* 
* |SYNC|  BP  |<-- HACTIVE -->|FP|SYNC|  BP  |<-- HACTIVE
* ______________________________
* |____|      VGA_HS      |____|
*/

// Parameters for hcount
parameter HACTIVE = 11'd 1280;
  HFRONT_PORCH = 11'd 32,
  HSYNC = 11'd 192,
  HBACK_PORCH = 11'd 96,
  HTOTAL = HACTIVE + HFRONT_PORCH + HSYNC + HBACK_PORCH; // 1600

// Parameters for vcount
parameter VACTIVE = 10'd 480;
  VFRONT_PORCH = 10'd 10,
  VSYNC = 10'd 2,
  VBACK_PORCH = 10'd 33,
  VTOTAL = VACTIVE + VFRONT_PORCH + VSYNC + VBACK_PORCH; // 525

logic endOfLine;
always_ff @(posedge clk50 or posedge reset)
  if (reset)   hcount <= 0;
  else if (endOfLine) hcount <= 0;
  else       hcount <= hcount + 11'd 1;
assign endOfLine = hcount == HTOTAL - 1;

logic endOfField;
always_ff @(posedge clk50 or posedge reset)
  if (reset)   vcount <= 0;
  else if (endOfLine)
    if (endOfField) vcount <= 0;
    else          vcount <= vcount + 10'd 1;
assign endOfField = vcount == VTOTAL - 1;

// Horizontal sync: from 0x520 to 0x5DF (0x57F)
// 101 0010 0000 to 101 1101 1111
assign VGA_HS = !((hcount[10:8] == 3'b101) &
   (hcount[7:5] == 3'b111));
assign VGA_VS = !((vcount[9:1] == (VACTIVE + VFRONT_PORCH) / 2);

assign VGA_SYNC_n = 1'b0; // For putting sync on the green signal; unused
// Horizontal active: 0 to 1279   Vertical active: 0 to 479
// 101 0000 0000 1280 01 1110 0000 480
// 110 0011 1111 1599 10 0000 1100 524
   (!(vcount[9] | (vcount[8:5] == 4'b1111)));

/* VGA_CLK is 25 MHz
* __________
*  __________
*  __________
*  __________
*  __________
*  __________
*  __________
*  __________
*  __________
*  __________
*  __________
*/
assign VGA_CLK = hcount[0]; // 25 MHz clock: rising edge sensitive
endmodule

define USB_GAMEPAD_H
#define USBGAMEPAD_H
#include <stdint.h>
#include <libusb-1.0/libusb.h>
#include <stdio.h>
#include <stdlib.h>
#include <arpa/inet.h>

#define USB_HID_INTERFACE_CLASS 0x03
#define USB_HID_GAMEPAD_PROTOCOL 0x00
#define LOGITECH_VENDOR_ID 0x046d
#define LOGITECH_F310PRODUCT_ID 0xc216

struct libusb_device_handle *open_gamepad(uint8_t *endpoint_address) {  
    libusb_device **devs;
    struct libusb_device_handle *gamepad = NULL;
    struct libusb_device_descriptor desc;
    ssize_t num_devs, d;
    uint8_t i, k;

    if (libusb_init(NULL) < 0) {
        fprintf(stderr, "Error: libusb_init failed\n");
        exit(1);
    }

    if ((num_devs = libusb_get_device_list(NULL, &devs)) < 0) {
        fprintf(stderr, "Error: libusb_get_device_list failed\n");
        exit(1);
    }

    for (d = 0; d < num_devs; d++) {
        libusb_device *dev = devs[d];
        if (libusb_get_device_descriptor(dev, &desc) < 0) {
            fprintf(stderr, "Error: libusb_get_device_descriptor failed\n");
            exit(1);
        }

        if (desc.idVendor == LOGITECH_VENDOR_ID && desc.idProduct == LOGITECH_F310PRODUCT_ID) {
            struct libusb_config_descriptor *config;
            libusb_get_config_descriptor(dev, 0, &config);
            for (i = 0; i < config->bNumInterfaces; i++) {
                for (k = 0; k < config->interface[i].num_altsetting; k++) {
                    const struct libusb_interface_descriptor *inter =
                        config->interface[i].altsetting + k;
                    if (inter->bInterfaceClass == USB_HID_INTERFACE_CLASS &&
                        inter->bInterfaceProtocol == USB_HID_GAMEPAD_PROTOCOL) {
                        int r;
                        if ((r = libusb_open(dev, &gamepad)) != 0) {
                            fprintf(stderr, "Error: libusb_open failed: %d\n", r);
                            exit(1);
                        }
                        if (libusb_kernel_driver_active(gamepad, i))
                            libusb_detach_kernel_driver(gamepad, i);
                    }
                }
            }
        }
    }
}
libusb_detach_kernel_driver(gamepad, 1);
libusb_set_auto_detach_kernel_driver(gamepad, 1);
if ((r = libusb_claim_interface(gamepad, i)) != 0) {
    fprintf(stderr, "Error: libusb_claim_interface failed:
\td\n", r);
    exit(1);
}
    *endpoint_address = inter->endpoint[0].bEndpointAddress;
goto found;
}
}
}
}
}
found:
libusb_free_device_list(devs, 1);

return gamepad;
}
#endif // USBGAMEPAD_H

Vga_ball.c

#ifdef USBGAMEPAD_H
#define USBGAMEPAD_H

#include <stdint.h>
#include <libusb-1.0/libusb.h>
#include <stdio.h>
#include <stdlib.h>
#include <arpa/inet.h>
#define USB_HID_INTERFACE_CLASS 0x03
#define USB_HID_GAMEPAD_PROTOCOL 0x00
#define LOGITECH_VENDOR_ID 0x046d
#define LOGITECH_F310_PRODUCT_ID 0xc216

struct libusb_device_handle *open_gamepad(uint8_t *endpoint_address) {
    libusb_device **devs;
struct libusb_device_handle *gamepad = NULL;
struct libusb_device_descriptor desc;
ssize_t num_devs, d;
uint8_t i, k;

if (libusb_init(NULL) < 0) {
    fprintf(stderr, "Error: libusb_init failed\n");
    exit(1);
}

if ((num_devs = libusb_get_device_list(NULL, &devs)) < 0) {
    fprintf(stderr, "Error: libusb_get_device_list failed\n");
    exit(1);
}

for (d = 0; d < num_devs; d++) {
    libusb_device *dev = devs[d];
    if (libusb_get_device_descriptor(dev, &desc) < 0) {
        fprintf(stderr, "Error: libusb_get_device_descriptor failed\n");
        exit(1);
    }

    if (desc.idVendor == LOGITECH_VENDOR_ID && desc.idProduct == LOGITECH_F310_PRODUCT_ID) {
        struct libusb_config_descriptor *config;
        libusb_get_config_descriptor(dev, 0, &config);
        for (i = 0; i < config->bNumInterfaces; i++) {
            for (k = 0; k < config->interface[i].num_altsetting; k++) {
                const struct libusb_interface_descriptor *inter =
                    config->interface[i].altsetting + k;
                if (inter->bInterfaceClass == USB_HID_INTERFACE_CLASS &&
                    inter->bInterfaceProtocol == USB_HID_GAMEPAD_PROTOCOL) {
                    int r;
                    if (((r = libusb_open(dev, &gamepad)) != 0) {
                        fprintf(stderr, "Error: libusb_open failed: %d\n", r);
                        exit(1);
                    }
                    if (libusb_kernel_driver_active(gamepad, i))
                        libusb_detach_kernel_driver(gamepad, i);
                    libusb_set_auto_detach_kernel_driver(gamepad, 1);
                    if (((r = libusb_claim_interface(gamepad, i)) != 0) {
fprintf(stderr, "Error: libusb_claim_interface failed: \n\n");
exit(1);
}

*endpoint_address = inter->endpoint[0].bEndpointAddress;
goto found;
}
}
}
}
}

found:
libusb_free_device_list(devs, 1);

return gamepad;
}

#endif // USBGAMEPAD_H

Gamelogic.h

#ifndef _HUARONGDAO_H
#define _HUARONGDAO_H

#include <linux/ioctl.h>

typedef struct {
    unsigned char x;
    unsigned char y;
} location_t;

typedef struct {
    unsigned char block_id;
    int type; // 0: Empty, 1: Normal Block, 2: Target Block
    location_t location;
} block_t;

typedef struct {
    location_t cursor_loc;
    location_t selected; // set to 4,4 if none gets selected
    unsigned char win;
}
block_t blocks[15];
) vga_ball_arg_t;

#define VGA_BALL_MAGIC 'q'

/* ioctls and their arguments */
#define VGA_BALL_WRITE_BACKGROUND _IOW(VGA_BALL_MAGIC, 1, vga_ball_arg_t *)
#define VGA_BALL_READ_BACKGROUND _IOR(VGA_BALL_MAGIC, 2, vga_ball_arg_t *)

#endif

Gamelogic.c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <arpa/inet.h>
#include <unistd.h>
#include "usbgamepad.h"
#include <stdint.h>
#include <stdbool.h>
#include "gamelogic.h"
#include <sys/ioctl.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <string.h>
#include <unistd.h>

struct libusb_device_handle *gamepad;
uint8_t endpoint_address;

block_t create_block(int id)
{
    block_t b;
    b.block_id = id;
    b.type = 1;
    return b;
};
int init;
char filename[] = "/dev/vga_ball";
unsigned char win;
void write2hw(vga_ball_arg_t vla)
{
  if (!init)
  {
    if ((vga_ball_fd = open(filename, O_RDWR)) == -1)
    {
      fprintf(stderr, "could not open %s\n", filename);
      return;
    }
    init = 1;
  }

  if (ioctl(vga_ball_fd, VGA_BALL_WRITE_BACKGROUND, &vla))
  {
    perror("ioctl(VGA_BALL_SET_BACKGROUND) failed");
    return;
  }
}

bool cursor_moving(block_t arr[4][4], location_t location, int direction);
bool block_moving(block_t arr[4][4], location_t location, int direction);
void block_to_string(block_t arr[4][4], location_t cursor_location);
void write_hw(block_t arr[4][4],
              location_t location, location_t selected_loc);
bool arrays_are_equal(block_t arr1[4][4], block_t arr2[4][4])
{
  for (int i = 0; i < 4; i++)
  {
    for (int j = 0; j < 4; j++)
    {
      if (arr1[i][j].block_id != arr2[i][j].block_id)
      {
        return false;
      }
    }
  }
  return true;
}
```c
int main()
{
    int err, col;

    struct sockaddr_in serv_addr;

    int transferred;
    // char keystate[12];
    char msg[128];
    memset(msg, 0, 128);

    /* Open the keyboard */
    if ((gamepad = open_gamepad(&endpoint_address)) == NULL)
    {
        fprintf(stderr, "Did not find a keyboard\n");
        exit(1);
    }

    // init() the game state
    // object: move the block to top right corner

    // level one: 15 blocks, target one block under on the right corner

    // we will have a blocks.c file to deal with block moving solely
    // for game logic, please implement in this file!

    // declare variables
    bool selected_block;
    int selected_block_id;
    location_t cursor_location, selected_loc;
    block_t block0;
    block_t block1;
    block_t block2;
    block_t block3;
    block_t block4;
    block_t block5;
    block_t block6;
    block_t block7;
    block_t block8;
    block_t block9;
    block_t block10;
    block_t block11;
```
block_t block12;
block_t block13;
block_t block14;
block_t block15;

win = 0;

// initialize variables
selected_block = false;
selected_block_id = 0;
cursor_location.x = 0;
cursor_location.y = 0;
selected_loc.x = 4;
selected_loc.y = 4;
block0 = create_block(0);
block1 = create_block(1);
block2 = create_block(2);
block3 = create_block(3);
block4 = create_block(4);
block5 = create_block(5);
block6 = create_block(6);
block7 = create_block(7);
block8 = create_block(8);
block9 = create_block(9);
block10 = create_block(10);
block11 = create_block(11);
block12 = create_block(12);
block13 = create_block(13);
block14 = create_block(14);
block15 = create_block(15);
block0.type = 0;
block1.type = 2;

// initialize block array

// block_t init_arr[16] = {block0, block1, block2, block3, block4, block5, block6, block7, block8, block9, block10, block11, block12, block13, block14, block15};

// set winning array

block_t arr[4][4] = {
    {block1, block2, block3, block4},
    {block5, block6, block7, block8},
    {block9, block10, block11, block12},
    {block13, block14, block0, block15}};

for (int i = 0; i < 4; i++)
```c
for (int j = 0; j < 4; j++)
{
    arr[i][j].location.x = j;
    arr[i][j].location.y = i;
}
}

block_t winning_arr[4][4] = {
    {block1, block2, block3, block4},
    {block5, block6, block7, block8},
    {block9, block10, block11, block12},
    {block13, block14, block15, block0}};

// random shuffle block array

// produce a set of array

// DISPLAY THE CURRENT GAMESPACE

write_hw(arr, cursor_location, selected_loc);

bool game_end = 0;

/* Look for and handle keypresses */
for (; ; )
{
    uint8_t data[8];
    int actual_length;
    int r = libusb_interrupt_transfer(gamepad, endpoint_address, data,
    sizeof(data), &actual_length, 0);

    if (r == 0 && actual_length == sizeof(data))
    {
        // Get pressed key
        uint8_t buttons = data[4];
```
// Sleep for 50 ms to avoid flooding the console with messages
// usleep(500);

// read game states:
// int

// game logic to handle block interaction based on the gamepad usage

// left 6, right 2, up 0, down 4, A 40, B 72, X 24, Y 136

if (buttons == 6 && game_end == 0)
{
    // printf("this is the left arrow button\n");
    if (selected_block == false)
    {
        // TODO
        // cannot move to empty space
        selected_loc.x = 4;
        selected_loc.y = 4;
        printf("move the cursor to the left\n");
        if (cursor_moving(arr, cursor_location, 1))
        {
            cursor_location.x -= 1;
            vla.cursor_loc.x = cursor_location.x;
            write_hw(arr, cursor_location, selected_loc);
            block_to_string(arr, cursor_location);
        }
    }
}

if (selected_block == true)
{
    // TODO
    // need to verify the blocks movability
    write_hw(arr, cursor_location, cursor_location);
    // printf("move the block to the left\n");
    if (block_moving(arr, cursor_location, 1))
    {
        block_t blk1 = arr[cursor_location.y][cursor_location.x];
        block_t blk2 = arr[cursor_location.y][cursor_location.x - 1];
        blk1.location.x --;
        arr[cursor_location.y][cursor_location.x - 1] = blk2;
        arr[cursor_location.y][cursor_location.x] = blk1;
cursor_location.x += 1;
write_hw(arr, cursor_location, cursor_location);

block_to_string(arr, cursor_location);
if (arrays_are_equal(arr, winning_arr))
{
    game_end =1;
    win =1;
    write_hw(arr, cursor_location, cursor_location);
    // break;
}
else if (buttons == 2 && game_end == 0)
{
    printf("this is the right arrow button\n");

    if (selected_block == false)
    {
        // TODO
        // cannot move to empty space
        selected_loc.x = 4;
        selected_loc.y = 4;
        // printf("move the cursor to the right\n");
        if (cursor_moving(arr, cursor_location, 3))
        {
            cursor_location.x += 1;
            vla.cursor_loc.x = cursor_location.x;
            write_hw(arr, cursor_location, selected_loc);
            block_to_string(arr, cursor_location);
        }
    }
}
if (selected_block == true)
{
    // TODO
    // need to verify the blocks movability
    write_hw(arr, cursor_location, cursor_location);
    printf("move the block to the right\n");
    if (block_moving(arr, cursor_location, 3))
    {
block_t blk1 = arr[cursor_location.y][cursor_location.x];
block_t blk2 = arr[cursor_location.y][cursor_location.x + 1];
blk1.location.x++;
arr[cursor_location.y][cursor_location.x] = blk2;
arr[cursor_location.y][cursor_location.x + 1] = blk1;
cursor_location.x += 1;

write_hw(arr, cursor_location, cursor_location);
block_to_string(arr, cursor_location);
if (arrays_are_equal(arr, winning_arr))
{
    game_end = 1;
    win = 1;
    write_hw(arr, cursor_location, cursor_location);
}
}
else if (buttons == 0 && game_end == 0)
{
printf("this is the up arrow button\n");
if (selected_block == false)
{
    // TODO
    // cannot move to empty space

    // printf("move the cursor to the up\n");
    if (cursor_moving(arr, cursor_location, 2))
    {
        cursor_location.y -= 1;
        vla.cursor_loc.y = cursor_location.y;
        write_hw(arr, cursor_location, selected_loc);
        block_to_string(arr, cursor_location);
    }
}
if (selected_block == true)
{
    // TODO
    // need to verify the blocks movability

    // printf("move the block to the up\n");
    write_hw(arr, cursor_location, cursor_location);
if (block_moving(arr, cursor_location, 2))
{
    block_t blk1 = arr[cursor_location.y][cursor_location.x];
    block_t blk2 = arr[cursor_location.y - 1][cursor_location.x];
    blk1.location.y--;
    arr[cursor_location.y][cursor_location.x] = blk2;
    arr[cursor_location.y - 1][cursor_location.x] = blk1;

    cursor_location.y -= 1;

    write_hw(arr, cursor_location, cursor_location);
    block_to_string(arr, cursor_location);
    if (arrays_are_equal(arr, winning_arr))
    {
        game_end = 1;
        win = 1;
        write_hw(arr, cursor_location, cursor_location);
    }
}

else if (buttons == 4 && game_end == 0)
{
    printf("this is the down arrow button\n");
    if (selected_block == false)
    {
        // TODO
        // cannot move to empty space
        write_hw(arr, cursor_location, selected_loc);
        // printf("move the cursor to the down\n");
        if (cursor_moving(arr, cursor_location, 4))
        {
            cursor_location.y += 1;
            vla.cursor_loc.y = cursor_location.y;
            write_hw(arr, cursor_location, selected_loc);
            block_to_string(arr, cursor_location);
        }
    }
}
if (selected_block == true)
{
    // TODO
// need to verify the blocks movability
write_hw(arr, cursor_location, cursor_location);

// printf("move the block to the down\n");
if (block_moving(arr, cursor_location, 4))
{
    block_t blk1 = arr[cursor_location.y][cursor_location.x];
    block_t blk2 = arr[cursor_location.y + 1][cursor_location.x];
    blk1.location.y++;
    arr[cursor_location.y][cursor_location.x] = blk2;
    arr[cursor_location.y + 1][cursor_location.x] = blk1;
    cursor_location.y += 1;

    write_hw(arr, cursor_location, cursor_location);
    block_to_string(arr, cursor_location);
    if (arrays_are_equal(arr, winning_arr))
    {
        game_end = 1;
        win = 1;
        write_hw(arr, cursor_location, cursor_location);
    }
}
}
else if (buttons == 40 && game_end == 0)
{
    // printf("this is the A button\n");
    if (selected_block == false)
    {
        selected_block = true;
        write_hw(arr, cursor_location, cursor_location);
        printf("select the current block\n");
        block_to_string(arr, cursor_location);
    }
    else if (selected_block == true)
    {
        selected_block = false;
        write_hw(arr, cursor_location, selected_loc);
        printf("un-select the block\n");
        block_to_string(arr, cursor_location);
    }
}
{
    printf("this is the B button\n");
}
else if (buttons == 24)
{
    block_to_string(arr, cursor_location);
}
else if (buttons == 136)
{
    printf("this is the Y button\n");
    win = 0;
    game_end = 0;
    size_t i;
    srand(time(NULL));
    block_t init_arr[16] = (block0, block1, block2, block3, block4, block5, block6, block7, block8, block9, block10, block11, block12, block13, block14, block15);
    for (i = 0; i < 16; i++)
    {
        size_t j = i + rand() / (RAND_MAX / (16 - i) + 1);

        block_t t = init_arr[j];
        init_arr[j] = init_arr[i];
        init_arr[i] = t;
    }
    for (int i = 0; i < 4; i++)
    {
        for (int j = 0; j < 4; j++)
        {
            arr[i][j] = init_arr[i * 4 + j];
            arr[i][j].location.x = j;
            arr[i][j].location.y = i;
        }
    }
    selected_block = false;
    write_hw(arr, cursor_location, selected_loc);
}
}
block_t *blockat(block_t blocks[4][4], int id)
{
    int i, j;
    block_t *b;

    for (i = 0; i < 4; i++)
    {
        for (j = 0; j < 4; j++)
        {
            if (blocks[i][j].block_id == id)
            {
                printf("1\n");
                b = &blocks[i][j];
                return b;
            }
        }
    }

    return b;
}

void write_hw(block_t arr[4][4], location_t location, location_t selected_loc)
{
    int i, id;
    block_t *block;
    for (id = 1; id < 16; id++)
    {
        block = blockat(arr, id);
        vla.blocks[id - 1].block_id = id;
        vla.blocks[id - 1].location.x = block->location.x;
        vla.blocks[id - 1].location.y = block->location.y;
    }
    vla.selected.x = selected_loc.x;
    vla.selected.y = selected_loc.y;
    vla.win = win;
    vla.cursor_loc.x = location.x;
    vla.cursor_loc.y = location.y;
for (i = 0; i < 15; i++)
{
    printf("block [%hu]-x: %hu, y: %hu\n",
            vla.blocks[i].block_id, vla.blocks[i].location.x,
            vla.blocks[i].location.y);
}
printf("cursor (%hu, %hu)\n", vla.cursor_loc.x, vla.cursor_loc.y);
write2hw(vla);
}

bool cursor_moving(block_t arr[4][4], location_t location, int direction)
{
    if (direction == 1)
    { // left
        if (location.x == 0)
        {
            return false;
        }
        else if (arr[location.y][location.x - 1].type == 0)
        {
            return false;
        }
        else
        {
            return true;
        }
    }
    else if (direction == 2)
    { // up
        if (location.y == 0)
        {
            return false;
        }
        else if (arr[location.y - 1][location.x].type == 0)
        {
            return false;
        }
        else
        {
            return true;
        }
    }
}
else if (direction == 3)
    { // right
        if (location.x == 3)
            {
                return false;
            }
        else if (arr[location.y][location.x + 1].type == 0)
            {
                return false;
            }
        else
            {
                return true;
            }
    }
else
    { // down
        if (location.y == 3)
            {
                return false;
            }
        else if (arr[location.y + 1][location.x].type == 0)
            {
                return false;
            }
        else
            {
                return true;
            }
    }
}

bool block_moving(block_t arr[4][4], location_t location, int direction)
{
    if (direction == 1)
    { // left
        if (location.x == 0)
            {
                return false;
            }
        else if (arr[location.y][location.x - 1].type != 0)
            {
                return false;
            }
    }
return false;
}
else
{
    return true;
}
}
else if (direction == 2)
{ // up
    if (location.y == 0)
    {
        return false;
    }
    else if (arr[location.y - 1][location.x].type != 0)
    {
        return false;
    }
    else
    {
        return true;
    }
}
else if (direction == 3)
{ // right
    if (location.x == 3)
    {
        return false;
    }
    else if (arr[location.y][location.x + 1].type != 0)
    {
        return false;
    }
    else
    {
        return true;
    }
}
else
{ // down
    if (location.y == 3)
    {
        return false;
    }
else if (arr[location.y + 1][location.x].type != 0)
{
  return false;
}
else
{
  return true;
}
}

void block_to_string(block_t arr[4][4], location_t cursor_location)
{
  printf("cursor: %d, %d\n", cursor_location.x, cursor_location.y);
  for (int i = 0; i < 4; i++)
  {
    for (int j = 0; j < 4; j++)
    {
      if (arr[i][j].type == 0)
      {
        printf(" 	");
      }
      else
      {
        if (cursor_location.x == j & cursor_location.y == i)
        {
          printf("%d\t", arr[i][j].block_id);
        }
        else
        {
          printf("%d\t", arr[i][j].block_id);
        }
      }
      // else if (arr[i][j].type == 1) {
      //   printf("%d\t", arr[i][j].block_id);
      //   // printf("X");
      // }
    }
  }
  printf("\n");
}
/return new array
// void shuffle_and_fill(block_t *init_arr, size_t len, block_t arr[][4])
// {
//   size_t i;
//   srand(time(NULL));
//   for (i = 0; i < len; i++)
//     {
//       size_t j = i + rand() / (RAND_MAX / (len - i) + 1);
//       block_t t = init_arr[j];
//       init_arr[j] = init_arr[i];
//       init_arr[i] = t;
//     }
//   for (int i = 0; i < 4; i++)
//     {
//       for (int j = 0; j < 4; j++)
//         {
//           arr[i][j] = init_arr[i * 4 + j];
//           arr[i][j].location.x = j;
//           arr[i][j].location.y = i;
//         }
//     }
// }