RMIT University

EEET2490 – Embedded System: OS and Interfacing, Semester 2024-1

ASSESSMENT 3 – GROUP WORK

OBJECTIVES

In this group project, students as a team work together to further sharpen their skills and enrich knowlege in OS and peripheral driver development.

DESCRIPTION

Students should read all of the tasks below before starting of implementation, since one task may support another task.

1. Continued Development For Bare Metal OS (~25%)

a) Display image, video, and font on the screen

So far, you have learnt all the basics about screen display, and can work well with it to draw with specific position and color. It is quite easy to draw a line, rectangle, circle on the screen. However, how about displaying images and videos?

In this task,

i. Select a nice image of which size is larger then scrensize and display it on screen that we can use '**w' and 's' keys** to scroll up and down.

ii. We can display images, how can we display a **video** on the screen? Think of it and find the answer for yourself. Select a video and display it on the screen. For the purpose of demonstrating, you only need to display a very-short video (just several seconds).

iii. Display names of all team members on the screen. You should use several <u>different colors</u> for the text.

<u>Supporting Resource</u>:

- This tool can help you to convert an image into ARGB32 data (select RGB888 option), which is compatible with our Raspberry Pi: https://javl.github.io/image2cpp/

  Note that, the tool convert an image into an array of data, in which each element is 32-bit data for each pixel. Follow the steps below

1. **Select Image**

All processing is done locally in your browser; your images are not uploaded or stored anywhere online.

Choose Files **17_PR_SYBO.jpg**

17_PR_SYBO.jpg **remove**

2. **Setting for Output: select 3 bytes per pixel (rgb888)**

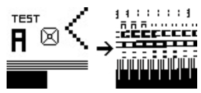
Code output format Arduino code

Adds some extra Arduino code around the output for easy copy-paste into [this example](). If multiple images are loaded, generates a byte array for each and appends a counter to the identifier.

Identifier/Prefix: epd_bitmap_

Draw mode: Horizontal - 3 bytes per pixel (rgb888)

If your image looks all messed up on your display, like the image below, try using a different mode.



Swap bits in byte: ☐ swap

Useful when working with the u8g2 library.

3. **Image Settings: select Black for Background color**

Canvas size(s): 17_PR_SYBO.jpg (file resolution: 710 x 355)

710 x 355 glyph **remove**

Background color: ○ White ◉ Black ○ Transparent

Invert image colors ☐

Dithering: Binary

Brightness / alpha threshold: 128

0 - 255; if the brightness of a pixel is above the given level the pixel becomes white, otherwise they become black. When using alpha, opaque and transparent are used instead.

4. **Check Preview:** *it should show your uploaded image with correct color. If not, reload the webpage and start again*

5. **Generate Code:** *it should now give you the pixel data of the image*

Generate code **Copy Output** **Download as binary file (.bin)**

```
// '17_PR_SYBO', 710x355px
const unsigned long epd_bitmap_17_PR_SYBO [] PROGMEM = {
	0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003d5acf, 0x003d5acf, 0x003d5acf,
0x003d5acf, 0x003d5acf, 0x003d5acf, 0x003d5acf, 0x003d5acf, 0x003d5ad0, 0x003d5ad0, 0x003d5ad0, 0x003d5ad0, 0x003d5ad0,
0x003d5ad0, 0x003d5ad0, 0x003d5ad0, 0x003c59ce, 0x003c59ce, 0x003c59ce, 0x003c59ce, 0x003c59ce, 0x003c59ce, 0x003c59ce,
0x003c59ce, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003d5ad0, 0x003d5ad0, 0x003d5ad0, 0x003d5ad0, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003d5ad0,
0x003d5ad0, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf, 0x003c59cf,
```

- Sample **video** can be found here (or you can firm your own video): https://sample-videos.com/

  Hint: to display a video, it is simply just to display all frame images of it. Thus, use a tool to extract frame images from your video. Search for the keyword "**extract frames from video**" and there is a plenty of tools and ways to do so.

- Besides images and videos, displaying a **text** on screen is a conventional need. Basically, it is similar to the way that we draw any thing on the screen – we need to draw at corresponding pixels. However, to make it simple, we should have **FONT** which defines pattern of each single character glygh.

  The pixel data for the character glyphs is usually stored as a bitmap. In a bitmap, each pixel is represented by a single bit. If the bit is 'ON' (value 1), the pixel is to be drawn in the foreground color; if 'OFF' (value 0), the pixel is set to the background color (hidden).

  Example of letter "A" in an 8x8 FONT:

```
0 0 0 0 1 1 0 0 = 0x0C
0 0 0 1 1 1 1 0 = 0x1E
0 0 1 1 0 0 1 1 = 0x33
0 0 1 1 0 0 1 1 = 0x33
0 0 1 1 1 1 1 1 = 0x3F
0 0 1 1 0 0 1 1 = 0x33
0 0 1 1 0 0 1 1 = 0x33
0 0 0 0 0 0 0 0 = 0x00
```

  The letter A above can be represented by just an array of 8 bytes : {0x0C, 0x1E, 0x33, 0x33, 0x3F, 0x33, 0x33, 0x00}.

  Thus, to have a font, you can get an existing font image, such as at https://fontmeme.com/fonts/static/235021/autolova-font-character-map.png then convert the image of each character into pixel data and implement it for your OS.

  However, to help you save time for this task, **a sample font data** will be provided for you.

References: those tutorials listed below could be good references to look at:

[1] https://github.com/bztsrc/raspi3-tutorial/tree/master/0A_pcscreenfont

[2] https://github.com/babbleberry/rpi4-osdev/tree/master/part5-framebuffer

2. Explore Other Features Of Raspberry Pi (~25%)

Select **ONE** of the following features, and research about it

- **Multicore**
- **Timers and Interrupts**
- **Direct Memory Access (DMA**)

Provide a tutorial document similar to the Lab Guide (continue from the project of screen display) that provide an example project with necessary explanation. The selected feature should be then applied to your work in Task 3.

Supporting Resource: those tutorials listed below could be good references to look at, however, your work should not be the same as them:

[1] https://github.com/babbleberry/rpi4-osdev/tree/master/part10-multicore
[2]https://www.youtube.com/watch?v=2dlBZoLCMSc&list=PLVxiWMqQvhg9FCteL7I0aohj1_YiUx1x8&index=9
[3]https://www.youtube.com/watch?v=4JtZQ88x5_c&ab_channel=LowLevelDevel

3. App Development For Bare Metal OS (~50%)

Develop a small game that player(s) use screen and keyboards to play the game.

Your game should have colors (rather than just black and white). Basic requirement is to only have one fixed stage, excellent goods should have at least two game levels.

For observation and troubleshooting purposes, the communication between the game application and the CLI terminal should be as follow:

- **Terminal Input**: The terminal can send characters to control the game; the game should respond with **ACK** (acknowledgment) or **NAK** (negative acknowledgment, meaning something's gone wrong) depending on the situation.
- **Data Logging**: The game should log information to the terminal. This technique is useful for troubleshooting issues over the long run. Logs should include:
    - The number of commands received.
    - The current UART configuration options in use.
    - Any other useful information that students like to send

Criterion for evaluation:

- Complexity of the game application
- How well it is written (variables, resources usage, coding style…)
- The communication between the game application and the CLI terminal.
- Creativity: a little of creativity is welcome, but not compulsory. It is okay to get the idea from existing game (but don't completely copy and paste source code of existing games or works of other students).

*Note that it is required to **test with the real board** for both Task 1 and 2 (after you complete the development with QEMU).*

Advice: Developing a small game is actually not difficult. If you haven't developed any game before, my advice is to try making a simple game on an drag-and-drop platform like Scratch https://scratch.mit.edu/

Try with **Make an Apple Catcher Game:** www.youtube.com/watch?v=jFVJdRLZoQ4

Or **How to Make a Shooter Game**: www.youtube.com/watch?v=QXru0rSV2ZQ

Implement a game with the guide above in Scratch to understand how we can make a game with Background image, sprites (player, opponent, obstacles or other objects in your game), and their interactions. Then, you can think of your own game and implement it in C in a similar way.

Report and Presentation

Complete your **report** with discussion of all parts. You should provide some background information, explanation for your work, and also include screenshots of output as evidence of a successful outcome. *A discussion on success and limitation of the outcome would be also meaningful.*

For presentation, please record a **video** of maximum 20 mins that present, explain and demonstrate your work. All members should present in the demo video.