Customer-Experience Enhancement System

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The Final Project Report for ESE 519: Embedded Systems (University of Pennsylvania)

Abstract:

The final project mentioned in this report is a design of a customer-experience enhancement system, which includes three parts: dino game, Pan-tilt camera, and LCD & Speaker. In the paper, we would like first to introduce the project, then we will talk about the problems the project aims to solve. We will also discuss our inspiration for the designed system, including the inspiration from the chrome dino game. The objectives of the project will also be pointed out. Then, a detailed description of the technical details, such as the circuit diagram, components list, and the troubleshooting process, will be discussed.

Introduction:

The inconvenience of taking care of the children has bothered the customers who go for service or business for a long time, and few ways are efficient enough to help the customer take care of the children. One possible option is to hire people for children-care services, which is expensive and may not be feasible for most general service institutions since they may not have much extra budget. Inspired by the idea of the chrome dino game, a design of the customer-experience enhancement system is proposed to provide a feasible and reliable way to take care of the children of customers when they come for service to improve customer experience further. The system combines the dino game, face tracking pan-tilt camera, and the LCD & Speaker arrangement for customer interaction for playing music.

In the paper, we will introduce the project's background(problem statement) first, then discuss the source of inspiration. Next, we will illustrate the system architecture and objects of this system. After giving this basic information about the project, we will show the technical details, such as the component lists, the connection diagram, the troubleshooting process, and the result.

Problem statement:

It is common to see many customers carrying their children in the customer waiting room. And this is very inconvenient for them since they need to focus on the service or the business they need to do, making it hard to distribute their attention to the naughty children. However, usually, they could not find a safe and reliable place to leave their children.

Admittedly, some options are employed to help with this problem. However, none of them could be feasible and effective for society. One possible option is to let the service provider, such as the bank and supermarkets, hire some people to take care of the children, which could bring too much investment. So this would be unaffordable for many small or medium institutions with insufficient extra money. Another option would be leaving the phone to the children, which is quite common nowadays since phones are almost necessary for everyone in this high-tech era. However, this still could not ensure 100% safety and is not feasible for anyone. This is because some places have a poor internet connection, which could lead to a failure in contacting the children. And children will get bored and try to go somewhere else for fun when there is no internet or poor internet, which will still bring the risk of losing the children. Also, some people are not wealthy enough to get a phone for each of their children, and giving their phone to children is also inconvenient since the customer may need to use the phone for the service.

Hence, a generally feasible solution to help customers take care of their children safely is in need.

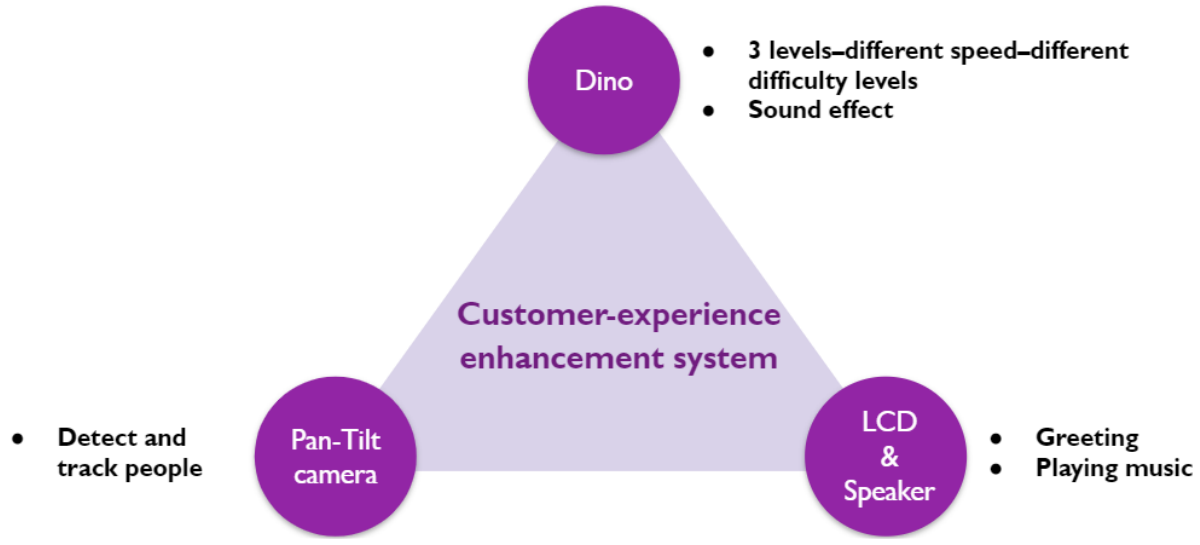
Inspiration of the project:

The idea of the chrome dino game inspires the concept of this customer-experience enhancement system. “ It is a play on going back to the “prehistoric age” when you had no Wi-Fi,” says the Chrome UX engineer Edward Jung. The chrome dino game was designed for website users to have fun when getting kicked offline, and it was deliberately kept simple and not boring so that everyone could get a good handle on it quickly and enjoy it. As a result, the chrome dino game was popular in countries with spotty data connections. It was so popular that some enterprise administrators had to disable it for the school kids and employees.

Inspired by its huge success and the problem behind it, we think this game could be perfectly embedded in the customer-experience enhancement system we design. Firstly, it could provide children with a way to have fun offline, reducing the risk of losing an internet connection. Also, games are always an excellent attraction to children, and this game is simple enough that anyone can play it without spending the time to learn the skills.

To better reduce the safety concern and provide a reliable for the customer to take care of their children, we also add the Pan-tilt camera and the LCD & Speaker. The pan-tilt camera is used for person detection so that it can track the children who are playing the game. If the camera loses sight of the children for a certain time, a warning message will be sent to the customer so that the customer can avoid dispersing their attention to worry about their children all the time. Children are also fascinated by these moving face tracking systems too, which not only serve the primary purpose but also act as a fun game for children and keep them busy. So a customer could peacefully do their purposeful work without worrying about their children. The combined use of LCD and speaker creates a human interaction since the children are also curious about these things and love greetings. And they could also play music based on their preference.

Project architecture and objectives:



The customer-experience enhancement system consists of three parts: The game part, the person detection part and the human interaction part.

- **Game part (Dino Game):** The dino game is one type that could be implemented using pico. We are using the dino game here since it can be played offline, and no skills are required. Moreover, we are using the famous and unique "pio" concept of the RP2040 microcontroller.
- **Person detection part:** The Pan-tilt camera is implemented in this part as a surveillance system for the children who will be playing the game. The camera will keep tracking the children as long as they are still in the playing room. The automatic face-tracking function could also be attractive and entertaining for kids. We will use the Raspberry Pi 4 for this part because PICO4ML or PICO had storage issues. It uses the OpenCV Machine Learning model "haarcascade_frontalface_default.xml" to detect faces.
- **Human interaction:** The LCD and the speaker are implemented together to create this human interaction interface. It will ask for the users' names and then give greetings. The user could also choose the music on the LCD based on preference. For this part, we again use the RP2040.

Components:

For this project, we used the following components:

SL No.	Component name	Quantity
1	Raspberry Pi Pico	2
2	Raspberry Pi 4	1
3	1.8inch TFT LCD Display ST7735	1
4	Mono class D audio amp with 8Ω 1W speaker	2
5	Push Button and its holder[3D Printed]	1
6	330Ω Registers	3
7	VGA Display with VGA connector	1

8	Arducam Pan Tilt and Picamera with SPI Interface	1
9	Switches	3

Operations/Functionalities:

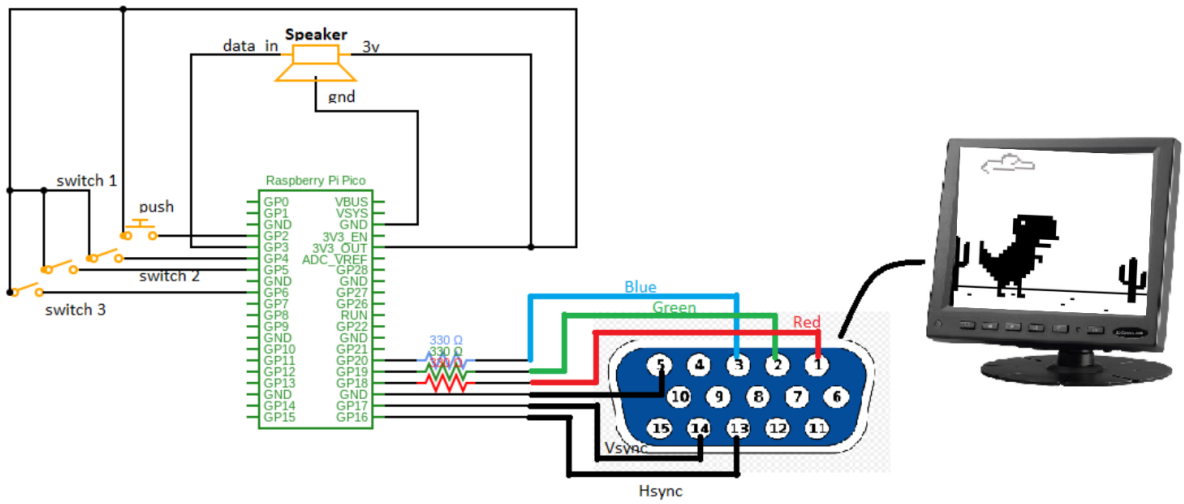
1. Dino Game:

Our aim in this game was to develop Google's Dino game using the Raspberry Pi Pico board, which has an RP2040 microcontroller.

The following features are included in this game:

1. It has three levels (level1 - easy, Level 2 - Medium, Level 3 - Hard). The difficulty at each level would rise in proportion to the increasing score.
2. The game has two sounds, one for the humping dino and the other when the "Game is Over" (Dinosaur crashes with the cactus and dies), signifying that the user input of button press supplied by the Game player was successfully executed. Moreover, make the game more interactive. A speaker was employed for this reason.
3. It employs a VGA display to display all visuals on the monitor. We leveraged the PIO functionality of RP2040 to achieve this feat of running the VGA display using the tiny and cheap Pico. We used bitmaps to draw the shape of a dinosaur and different types of cacti.
4. For user interaction, we used a "glowing" big push button, for an interactive user experience.
5. We also created different high-score buffers for different levels. The aim was to keep track of the highest score achieved at each level. Moreover, to create a competition during the demo day to beat the highest score. This makes the game more user interactive and fun.

Circuit Diagram:



In this circuit, Raspberry Pi Pico "GP16" and "GP17" were linked to HSync and VSync on the VGA connection, respectively. GP18, GP19, and GP20 were linked to the Red, Green, and Blue pins of VGA connections through 330 resistors apiece, which aids in the passage of the colors red, green, and blue. Both Vsync and Hsync were employed to keep the synchronization while performing operations. To play sound as the Dino jumps, we utilized a Mono class D audio amp with an 8 1W speaker in this game. There are three pins on this speaker: data, ground, and power. So we connected the data pin to "GP3", the ground pin to GND, and the power pin to "3V3 OUT" in this case. We utilized one push button to allow the Dino to jump, with one pin linked to "GP2" and the other grounded. We also employed additional 3 switches as level level setters and these switches were linked to "GP4", "GP5", and "GP6".

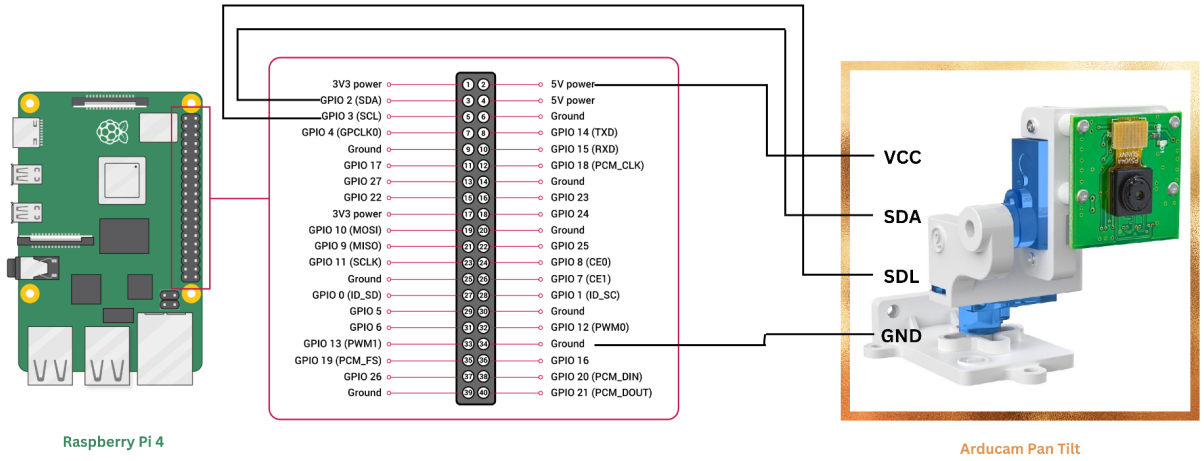
2. Person Detection:

This element of our project was utilized to recognize faces and shift the pan tilt to that direction dependent on the movement of the individual. This enables face tracking feature.

This work includes the following features:

1. It houses the Raspberry Pi Camera Module V2 on the Arducam Pan Tilt arrangement. This coordinated movement of servos and cameras enables the functionality of face tracking.
2. It identifies humans by using the openCV library and Machine Learning model “haarcascade_frontalface_default.xml” to detect faces and put a frame around them.
3. Its pan tilt camera would move up/down and left/right based on the person's movement measuring the relative movement of the frame and trying to reduce the positional error by moving the servos and hence the camera.

Circuit Diagram:



We had to utilize certain built-in OpenCV libraries for our Human face detection, and we had to use Raspberry Pi 4 for all calculations. Following the first hardware configuration, we had to install the Raspbian OS into its memory. For our Person's position tracking, we additionally employed an Arducam Pan tilt with an I2C interface. It has pins such as VCC, SDA, SDL, and GND. We applied 5v power to the "VCC pin" and grounded the "GND pin". The Raspberry Pi 4 contained two SDA and SDL lines, referred to as GPIO 2 and GPIO 3, respectively. Both were attached to our "SDA" and "SCL" pins. We utilized Mu Editor to write OverCV library-based Python code for code execution.

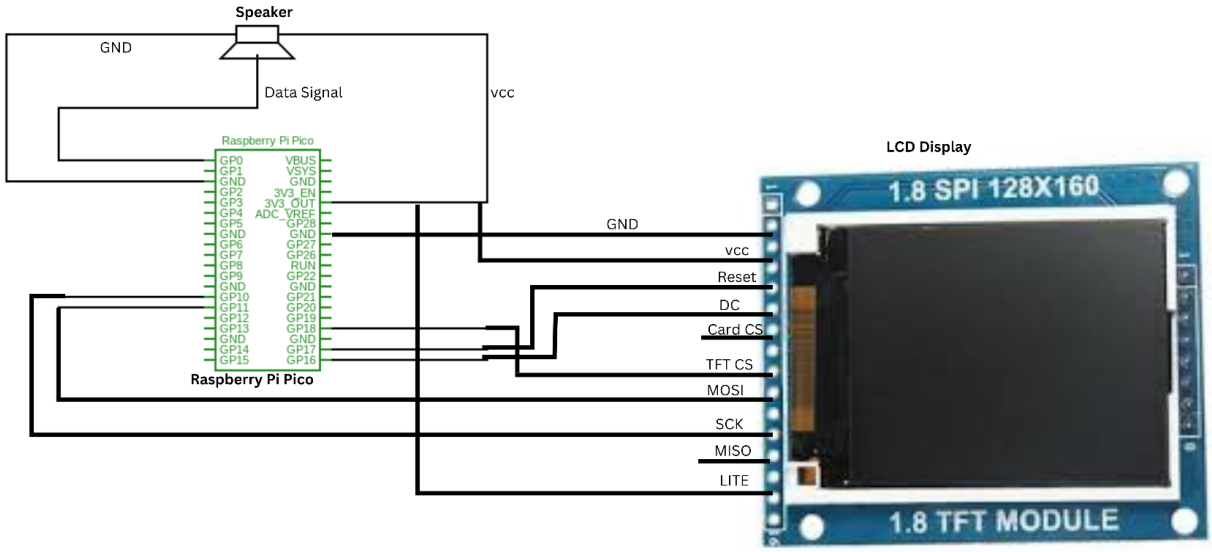
3. Human Interaction Interface:

This portion of our project was leveraged to construct a user interactive interface like "Google Assistant".

This work includes the following features:

1. It asks the person's name.
2. It greets the user by name, asks if they want to listen to music, and suggests some songs.
3. It plays the music based on various interest filters.

Circuit Diagram:



We deployed a Raspberry Pi Pico, a ST7735r 1.8' TFT display, and a Mono Enclosed Speaker - 3W 4 Ohm to show the user all of the text and visuals while also playing music. We used the pins on the 1.8 TFT display such as GND, VCC, DC, TFT CS, MOSI, SCK, and LITE to communicate effectively between the Raspberry Pi Pico and the TFT display. We had applied 3.3 Volt power to both the VCC and LITE pins, as well as the grounded GND pins. RESET, TFT CS, DC, MOSI, and SCK pins were also linked to the Raspberry Pi Pico's GP17, GP18, GP16, GP11, and GP10, respectively. We also utilized one speaker to play music, with the pins Data Signal, VCC, and GND connected to the Pico's GP0, 3.v Power, and ground pins, respectively. We were previously making some noises while playing music. We employed a 1 Nano-farad capacitor in shunt with the data stream for this purpose. It was able to attenuate noise to some extent.

Troubleshootings:

We worked with various components on this project, therefore certain Wrong Circuit Connections, Debugging problems, Run Time Errors, and so on were inevitable. The following are some of the troubleshooting steps we took during this project.

Dino Game :

Problem 1: No VGA signal was detected on the computer screen.

Debugging+Solution:

a. Use the oscilloscope to test signal→ signal is transmitted properly.
b. Change the DVI to VGA cable to the normal VGA cable.

Result: VGA signal detected

Problem 2: VGA signal detected, nothing displayed.

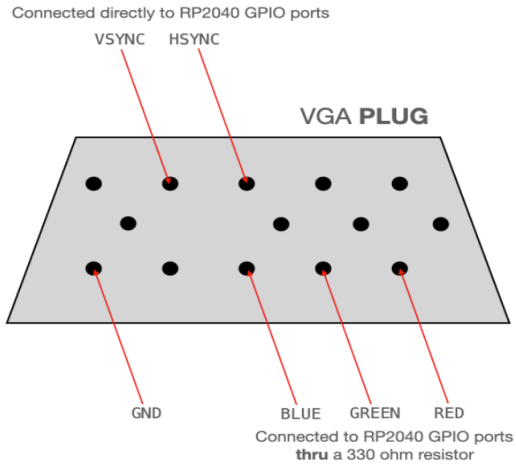
Debugging and Solution:

a. Used 330 k ohm instead of 330 ohm.
b. Solution: Replace all the resistors to 330 ohm(2*150 ohm,3*10 ohm, connected in series)

Result: The example code is working

VGA connection diagram:

Within the display, there is a 70 ohm resistor to ground. So, putting a 330ohm resistor between the GPIO ports and the VGA connector creates a voltage divider that keeps the output voltage within a safe range for the display.



- **Problem 3:** The push button is not working.

  Debugging and Solution: Wrong connecting way of push button—correct the connection.

- **Problem 4:** There is some display issue.

  Debugging and Solution: Solved using the vga_graphics.c functions.

- **Problem 5:** How to create images of dinosaurs and cactus.

  Debugging and Solution: Use Bitmaps.

- **Problem 6:** Adding Sound Effects.

Debugging and Solution: -Currently we are able to generate any mp3 audio to speaker PWM output. But that is not working in dino games. So currently working on it.

- **Problem 7:** Adding Sound Effects to the game.
  Debugging and Solution: The problem we faced was because their were interrupts already present in the game. Now the PWM sound code also is based on IRQ. Hence, it caused the issue. Thus to solve the issue we had to create another separate pwm driver c code "pwmsnd" to enable the synchronized functionality of game and sound.
- **Problem 8:** The Push button is too small and does not feel nice while playing.
  Debugging and Solution: We used a big "light enabled" push button and we designed a 3-D printed model to hold the button.
- **Problem 9:** Wanted to make the game more interesting.
  Debugging and Solution: Created 3 different levels, with different high score buffers to keep the game interesting and competitive.

Face Detecting Pan-Tilt Camera

Problem 1: In this step, we first considered using the Arducam on the Pico4ML board to detect humans. However, this board's storage capacity was only 2MB. And after we installed Circuitpython, this memory space was reduced to 0.9MB.

Debugging and Solution: Then we decided to implement this part of the project using the Raspberry Pi 4 board in order to get some functionality working before the demo day.

Problem 2: Finding Proper Machine Learing Model to efficiently detect the person's face using the specifics of camera.

Debugging and Solution: We found the the "haarcascade_frontalface_default.xml" to be very efficient for our camera and a low size model.

Problem 3: Issue while moving servos

Debugging and Solution: Pimoroni Pan-Tilt hat: uses PIC 16F 1503 with custom hardware and talks over I2C. However, the ArduCam Pan Tilt platform did not have any such servo-driver boards. The PIC 16F 1503 has a wide range of libraries that has been already used by users in face recognition pan tilt. However, the Arducam's library is pretty limited. Hence, most of the programs already presented on the internet do not work.

We found adafruit has a servo motor library named "adafruit_servokit", which was a very useful point of reference for designing our program which is related to controlling the Pan-Tilt.

We had to create our own functions to provide accurate shift angles related to the person's movement.

Problem 4: Adjusting the proportional Movement and the default angle.

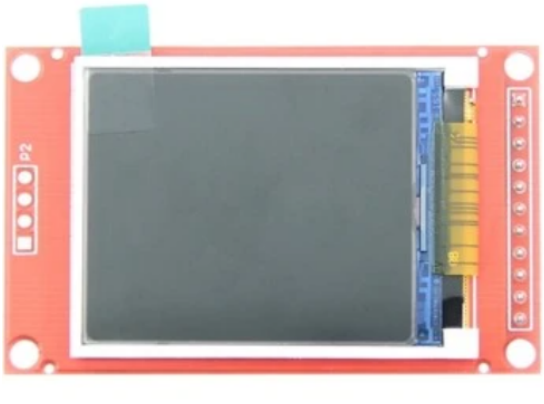
Debugging and Solution: It was a time consuming process and required a lot of fine tuning. It was a matter of experimenting with different values until we found the optimal values of proportional turns, error compensations and default angles, to make our person tracking feature flawless.

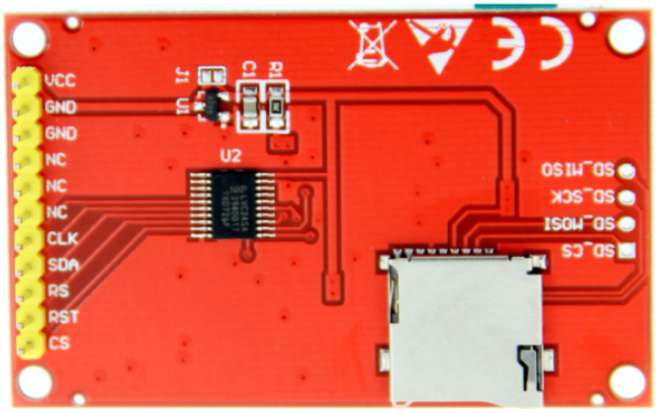
Human Interaction Interface:

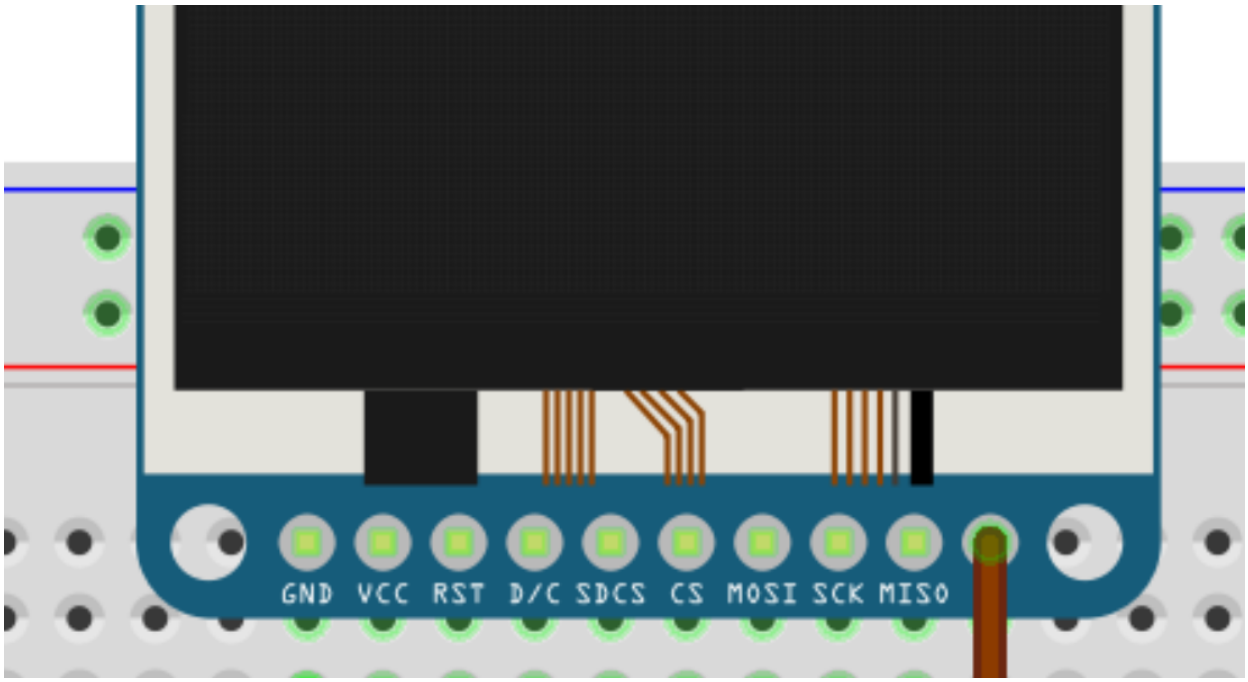
Issue 1: Display issue

1. There is blacklight in the LCD, which means it is functioning well, but no images displayed as expected.
2. The ST7735 used in the example has a different Pin number, which means the jump wire connection will be different.

Debugging and Solution: we find the pin function distribution of the ST7735 used in the video and the Pin value defined in the code to determine the wire connection.Then, we also find the Pin distribution of the ST7735 we are going to use, connect it based on the wire connection.







Issue 2: input issue

1. The ICD is functioning, however, it could not display an input of more than two characters. The solutions mentioned online have been tried but failed.

Debugging and Solution: We used the circuit python instead.

Issue 3 - Storage Issue:

1. Previously, we intended to utilize "Mono class D audio amp with 8 1W speaker" while working with the speaker for music playback. We had to save some mp3 files in the Raspberry Pi Pico's circuit python library. However, the Pico's 2MB on-board QSPI memory and 264KB on-chip RAM were insufficient for storage.

Debugging and Solution: Because Mp3 files take up more memory, we had to compress some of them, eliminate some unneeded program files from the CircuitPython Library, and then store some highly compressed mp3 files in it.

Issue 4 - Noise Issue:

1. Despite the fact that we fix Issue 3 by reducing the music files and eliminating certain unneeded files from the circuit python library. However, when playing the song, we heard a lot of noise.

Debugging and Solution: To address this, instead of a 1W speaker, we utilized a Mono Enclosed Speaker - 3W 4 Ohm, which considerably enhanced audio quality. In addition, a 1nF capacitor was shunted with the Data signal and ground.

Future Scope:

Although improving the customer experience and providing an exciting experience has always been an aim of society. This is a large project with a lot of room for growth in the future. We've just mentioned a handful of them here.

1. In the Dino Game section, visitors can select the game they wish to play. So, instead of just one option for playing the Dino Game, we'll provide you with a range of fun to play.
2. Face tracking pan tilt will notify the parent of the child who will be playing if it does not identify the child for more than 5 minutes. It would serve as a surveillance device, tracking children while they played.
3. For human interaction, we can upgrade it to make it behave like a "Google Assistant," which can display real-time statistics such as temperature and pressure and chat with the user as a virtual assistant.

Conclusion:

Although society has always sought to improve the consumer experience and offer an engaging experience, this sizable project has a lot of potential for future expansion. We can link Pico with various components and experiment with their register values, thanks to the efficient and unique PIO functionality and the many communication protocols provided in RP2040. The best part is that RP2040 Pio provides these comprehensive functionalities at a very cheap cost with a highly portable design.