Component Analysis

Year: 2023 Semester: Spring Team: 3 Project: ”Rigged” Card Shuffler

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Assignment Evaluation:

| **Item** | **Score (0-5)** | **Weight** | **Points** | **Notes** |
| --- | --- | --- | --- | --- |
| **Assignment-Specific Items** | | | | |
| **Analysis of Component 1** |  | x2 |  |  |
| **Analysis of Component 2** |  | x2 |  |  |
| **Analysis of Component 3** |  | x2 |  |  |
| **Bill of Materials** |  | x6 |  |  |
| **Writing-Specific Items** | | | | |
| **Spelling and Grammar** |  | x2 |  |  |
| **Formatting and Citations** |  | x1 |  |  |
| **Figures and Graphs** |  | x2 |  |  |
| **Technical Writing Style** |  | x3 |  |  |
| **Total Score** |  | | |  |

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

General Comments:

1.0 Component Analysis:

Our card shuffling machine’s design consists of four major components: a microcontroller, a single-board computer (SBC), an embedded camera, and a motor. The microcontroller holds central control of the entire machine, routing data and controlling internal mechanical systems to identify, shuffle, and output cards. The SBC holds the machine’s intelligence, using image data to recognize cards and defining a sort order directive that the microcontroller uses to output the cards according to user specification. The embedded camera module is used simply to snapshot cards for identification via the SBC. Finally, the primary motor controls the card binning wheel used to separate identified cards for permutation and reordered output. These four components have some constraining requirements, including intercompatibility and minimum required features, all of which are listed, analyzed, and compared in the following sections.

1.1 Analysis of Component 1: Microcontroller

The choice of microcontroller for our project is between a STM32 and an ESP32 microcontroller. More specifically, the STM32f091rct6 and the ESP32 Wroom 32 microprocessors. The stm32 microcontroller has more standard development environments whereas the esp32 has access to many different development languages and environments to be used during prototyping. Both microcontrollers have a C based development environment being System Workbench or CubeIDE for the STM32 and the Espressif-IDE for the ESP32. Unlike the ESP32, the STM32 microcontrollers can be very difficult to find tutorials or examples of as they are not common for hobbyists, however, the STM32 microcontroller is the same one used in ECE 362 so there is some amount of familiarity with C development for it.

| Feature | STM32f091rct6 [2] | ESP32 Wroom 32 [1] |
| --- | --- | --- |
| # of GPIO Pins | 52 | 32 |
| # of SPI Connections | 2 | 2 |
| # of UART Connections | 8 | 3 |
| # of Timers | 12 | 3 |
| Flash Memory | 128-256 KB | 448 KB |
| SRAM | 32 KB | 520 KB |
| Operating Voltage | 3-3.6 V | 3-3.6 V |
|  | CHOSEN |  |

Both chips have enough SPI and UART connections as well as GPIO Pins. The main reason that the STM32f091rct6 is being chosen is that it not only fulfills the main requirements but will give us some amount of a buffer if there are features that we need/decide to add in order for either normal function or for stretch goals. The stm32 microcontroller is also much more familiar for me to develop in C, however, the esp32 microcontroller will likely be used a large amount in prototyping the software, likely using micropython.

1.2 Analysis of Component 2: Single-Board Computer

The device requires a single-board computer to perform image recognition, to find valid card orders, and to communicate this data to the microcontroller. Ultimately, the two single-board computers in consideration are the Raspberry Pi 3 B and the NvidiaJetson Nano. While both of these boards have hobbyist communities (which is not necessarily a negative, as this generally increases the amount of relevant accessible resources), they are also often sold to OEM partners who integrate such SBCs into their products.

| **Feature** | **Raspberry Pi 3 B** [5] | **Nvidia Jetson Nano** [6] |
| --- | --- | --- |
| Price | $35 | $150 |
| CPU | ARM Cortex-A53 @1.2GHz | ARM Cortex-A57 MPCore @1.43GHZ |
| GPU | Dual Core VideoCore IV Multimedia Co-Processor | Nvidia Maxwell GPU |
| Memory | 1GB LPDDR2 | 4 GB LPDDR4 |
| GPIO Pins | 28 | 14 |
| UART | Yes | Yes |
| Display Interface | Yes | Yes |
| Camera Interfacing | Yes | Yes |
| Availability | Yes, via ECE 477 course staff | Yes |
| Selected? | Yes | No |

Immediately, the first factor any analysis will uncover is the disparity in price point for these two devices. The RPi 3 B can be found for around $35, although availability may be questionable as the chip shortage’s effects continue. The Nvidia Jetson Nano, on the other hand, was released to be around $100, but is typically found around $150 today. Based on this factor alone, the Raspberry Pi has a huge advantage as including the Jetson Nano would significantly raise the price of the product, which may price out some consumers that would otherwise purchase a controllable card shuffler.

The next factor that becomes apparent is the gap in computational power. The Jetson Nano outclasses the Raspberry Pi in terms of its CPU, GPU, and memory. However, because we are performing simple symbol, character, and color recognition, the Raspberry Pi’s computational power should suffice. In this case, then, the Jetson Nano’s computational power may actually be excessive, and thus the edge once again goes to the Pi.

The single-board computer will also need to communicate with the microcontroller and take pictures of the cards. This functionality is present on both single-board computers.

With these factors in mind, the Raspberry Pi 3 B seems to fit the project’s needs much better than the Jetson Nano, and is therefore the selection for this component.

1.3 Analysis of Component 3: Camera

Next is the camera module being used with the single-board computer (SBC). As previously mentioned, we will be using a Pi 3, so this section is heavily tailored to cameras compatible with that SBC. Here, we will compare the official Raspberry Pi camera module alongside a third-party Pi-compatible camera. Many alternative cameras exist as well, but these two provide a reasonable representation of Pi-compatible embedded camera modules that cost less than $50. The following table contains key hardware specifications and capabilities for those two camera modules.

| Feature | RasPi Camera Module [3] | Arducam Mini 2MP+ OV2640 [4] |
| --- | --- | --- |
| Price | $25 | $26 |
| Size | 25 × 24 × 9 mm | 34 × 24 × 15(est.) mm |
| Sensor | 8MP Sony IMX219 | 2MP OmniVision OV2640 |
| Sensor Size | 1/4” (quarter inch) | 1/4” (quarter inch) |
| Effective Focal Length (EFL) | 3.04 mm | 4.9 mm |
| Horizontal FOV | 62.2° | 60° |
| SBC Compatibility | Raspberry Pi | MCU, RasPi, ARM, DSP, FPGA |
| Data Output Format | PNG + (RGB or YUV) | JPEG + RGB |
| SBC Communication | Built-in official ribbon connector cable | External I2C (for configuration) and SPI (for data) interfaces |
| Availability | Via ECE 477 course staff | Multi-week international shipping |
| Selected? | Yes | No |

Like most embedded camera options, the two in consideration here are relatively cheap, coming in at roughly $25 each. Furthermore, they fit within relatively similar spatial dimensions. In terms of the varieties of sensors, most camera modules feature either a Sony or OmniVision sensor, with modern modules leaning predominantly towards the Sony offerings. The two brands’ camera sensors provide similar performance, with similar FOVs and sensor sizes. However, the Sony module provides better focal lengths, in turn providing sharper images at reduced distances, which will be critical in our shuffler device.

The differences only grow from there. More important than sensor specifications, which we should not exceed in our use case, is the camera housing and compatibility with our SBC. Although both types of camera modules are technically compatible with the RasPi, the official Pi camera modules have a clear win. Whether in terms of ease of integration due to having built-in communication channels or a wider variety of data storage and format options, the official Pi modules integrate far better and far more easily with the SBC in our design than third party modules. This is particularly apparent in the output data formats for the two analyzed camera modules. On the one hand, the official module supports the YUV image data format which is ideal for our card recognition application. On the other hand, not only does the unofficial module provide RGB data that requires additional pre-processing, but it also applies JPEG compression to the data beforehand, introducing unnecessary noise that could negatively impact image processing.

Finally, most importantly the official Pi camera is available directly from course staff, which eliminates the need to wait for part purchase and shipping. As a result, whether in terms of slightly better photo-capture capabilities related to improved focal lengths or far superior integration prospects with our SBC, the official Pi camera module is the best choice for our card shuffling machine.

1.4 Analysis of Component 4: Motor

For the motor we debated between using a DC motor vs a stepper motor. The benefit to both of these motors is that they have enough torque to efficiently rotate the wheel even when the wheel will have the greatest amount of resistance. Both of the motors are also able to change direction at ease, which is essential for our design. However, we decided to go with the stepper motor due to the fact that we will have precise control of where the motor will be and can control how much it rotates. The problem with the DC motor is that we cannot control how much it turns since the DC motor does not stop spinning when we cut the power being applied to it.

For our project in particular we are using the NEMA 17. This is because it was the cheapest stepper motor that was available. It has enough torque to reliably move the motor as desired and a small enough step size that it will be able to line up the shelves so that cards can be inserted and retrieved from the shuffler wheel [7].

2.0 Sources Cited:

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[7] “NEMA 17 Stepper Motor,” *Components 101*. [Online]. Available: <https://components101.com/motors/nema17-stepper-motor>. [Accessed: 04-Feb-2023]