Component Analysis

Year: 2022 Semester: Fall Team: 05 Project: Metaporter

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Assignment Evaluation:

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| --- | --- | --- | --- | --- |
| **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:

The primary hardware components of our design include the microcontroller, an LCD screen, an IMU, a keypad, a camera, and the Jetson Nano. The user can use the keypad to navigate through the LCD screen in order to start a scanning process. The IMU and camera will be the primary sources of data collection during a user-invoked scanning process. The LCD display will closely monitor the status of the device and give prompt updates during the scanning process. The microcontroller is responsible for managing the user input, updating the LCD display periodically, and transferring IMU data to the Jetson Nano. Lastly, the Jetson Nano is responsible for gathering IMU and camera data and conducting sensor fusion. A description and breakdown of each component criteria are listed below.

1.1 Analysis of Component 1: MCU

The microcontroller contributes a big part to our project. Namely, our microcontroller of choice must have plenty of I/O and communication channels to fit what we need. It must have a plethora of DMA channels to accelerate I/O tasks, be readily available amid the chip shortage, and needs to be relatively inexpensive to compensate for other costly components. Our chips of interest were STM32F091RCT [7] made by ST Microelectronics, S6E1A12B0AGP [8] made by Cypress, and RP2040TR13 [9] made by Raspberry Pi.

|  |  |  |  |
| --- | --- | --- | --- |
|  | STM32F091RCT6 | S6E1A12B0AGP | RP2040TR13 |
| # of DMA channels | 12 | N/A | 12 |
| 2 I2C channels | Yes | Yes | Yes |
| Additional  SPI channel | Yes | Yes | Yes |
| Additional  UART channel | Yes | Yes | Yes |
| Internal Flash Memory | 128KB | 88KB | N/A  (16KB of ROM with QSPI) |
| Ram | 32KB | 6KB | 264KB |
| Hand solder package | Yes  (LQFP64) | Yes  (LQFP: LQB032) | Yes  (QFN56) |
| Maximum Power Consumption (All clocks enabled, ~45°C) | 16mA  (48Mhz clk) | 12mA  (40Mhz clk) | 23mA  (133Mhz clk) |
| Availability | Yes | Yes | Yes |
| Cost | Free | $3.90 | $1.00 |

Since our microcontroller mostly deals with I/O-bound tasks, CPU performance will not be a metric in our comparison. Instead, the amount of flash and ram memory will be considered as more flash storage eliminates the need for external memory, and more RAM provides the flexibility to implement a larger buffer to optimize our workload. Additionally, supplemental metrics such as power consumption and the ability to hand solder are also included to provide a comprehensive comparison.

As listed in the comparison, the three chips that are currently available have vastly different characteristics. For example, S6E1A12BOAGP is more power efficient as it runs under a lower clock speed of 40Mhz. Nonetheless, no dedicated DMA channel and fewer RAM means that this chip won't suffice our application’s needs since it provides no viable means to accelerate I/O tasks.

On the other hand, RP2040TR13 has more than enough RAM for what we need. Even though our software employs a simple, single thread routine, this MCU has a higher system clock speed of 133Mhz and a two core Cortex M0+ processor. However, core counts are not taken into consideration as a metric, and the absence of internal flash memory creates unnecessary complexity to implement external flash memory. In addition, the package format of QFN is harder to hand solder than LQFP as the ground pad needs to be soldered under the chip.

Therefore, STM32F091RCT6 is our pick given our project constraints. It has enough flash and RAM compared to its counterparts, and there are plenty DMA, I2C, SPI, and UART channels for the project. It is more than sufficient for our needs despite having average power consumption and CPU speed.

1.2 Analysis of Component 2: IMU

Our project’s success is almost entirely dependent on collecting accurate data on our subject with respect to the handheld device. The IMU necessary to gather this data is crucial to our SLAM and sensor fusion algorithms for generating a proper 3D model; therefore, we researched three components and narrowed them down using these six factors: accelerometer, gyroscope, magnetometer, power modes, availability, and cost. The three IMUs we took into consideration were the BMX160 9-axis sensor from Bosch Sensortec [13], iNEMO 6DoF sensor from STM [14], and the ICM-20948 sensor from TDK [15].

|  |  |  |  |
| --- | --- | --- | --- |
|  | BMX160 9-axis sensor [13] | iNEMO 6DoF sensor [14] | ICM-20948 sensor [15] |
| Accelerometer | 3-axis | 3-axis | 3-axis with programmable FSR |
| Gyroscope | 3-axis | 3-axis | 3-axis with programmable FSR |
| Magnetometer | 3-axis | N/A | 3-axis compass (no magnetometer) |
| Gyroscope angular sensitivity  (LSB/dps) | 32.8  (full scan 1000, typ) | 35  (fs 1000, typ) | 32.8  (fs 1000, typ) |
| Acc. RMS Noise  (mg(RMS)) | 1.8 | 2.4 | 3.1 |
| Power Modes | Normal, low power, & sleep | Normal & high-performance | One mode (@ 2.65 mW) |
| Operating Voltage | 3.3-5.5V | 1.71-3.6V | 1.71-3.6V |
| Availability | Yes | Yes | Yes |
| Price | $13.90 | $6.18 | $7.78 |

When looking for the appropriate IMU, it was important that it has the proper accelerometer, gyroscope, and magnetometer. A 3-axis accelerometer would be able to accurately detect the rate at which the velocity of the device changes during data collection. In addition, a 3-axis gyroscope would enhance the data collection by factoring in angular velocity. Without a magnetometer, we wouldn’t be able to obtain the absolute coordinate vector and therefore adjust the offset value in accordance with the normal of the earth. Since the handheld device will be rotating along all axes, we need a direct measure of yaw.

Furthermore, one of the major distinctions when choosing an IMU would be its noise and sensitivity. Under normal mode for all three devices with scanning frequencies of 1000Hz, the angular sensitivity between the three devices is almost identical, but BMX160 has a leading edge when it comes to accelerometer noise.

Therefore, given the lower accelerometer noise and 3-axis magnetometer, we will be using the BMX160 9-axis IMU to collect the most accurate data with our device.

1.3 Analysis of Component 3: Display

An LCD is a very important part of Metaporter as it will serve as the user interface for the entire reconstruction process. As such, we needed to find an LCD that was large enough to display detailed updates of what is happening in the background of our project. Overall, screen size, color, resolution, and price were the main factors that we considered before acquiring an LCD. The three that we considered were the MSP2022 SPI TFT LCD [4], SOC1602A OLED LCD [5], and the EVE4 IPS 3.5" LCD TFT [6]

|  |  |  |  |
| --- | --- | --- | --- |
|  | MSP2022 SPI TFT LCD | SOC1602A OLED LCD | EVE4 IPS 3.5" LCD TFT |
| View Size(mm) | 33.84x45.12 | 66.0 x 16.0 | 70.08 x 52.56 |
| Color | RGB 65K color | White Only | RGB |
| Resolution | 320 x 240 pixels | Unknown | 320 x 240 pixels |
| Price | $10 | $19.99 | $60 |

After making the comparisons between these three LCDs, we decided to go with the MSP2022 SPI TFT LCD. One of the main benefits of this LCD is that it has color, which may help in alerting the user about the status of the reconstruction. It is also significantly cheaper than the EVE4 IPS LCD, while also being a better size for our handheld device.

1.4 Analysis of Component 4: Camera

A high-definition camera is essential for obtaining detailed images during the data collection process for our project. Without the appropriate camera component, Metaporter will not be able to create an accurate 3D rendering of a subject, so throughout our search, we compared five necessary features. Factors such as compatibility, field of view, max resolution, frame rate, and price were all considered before choosing our camera module. Three different types of cameras were examined throughout this process: IMX219-160 camera module [1], Raspberry Pi Camera Module 2 [2], and MINI IMX219 camera module [3].

|  |  |  |  |
| --- | --- | --- | --- |
|  | IMX219-160 Camera Module [1] | Raspberry Pi Camera Module 2 [2] | MINI IMX219 Camera Module [3] |
| Compatibility | Yes | Yes | Yes |
| Field of View | 160° | 62.2° | 110° |
| Max Resolution | 1080p | 1080p | 1080p |
| Frame Rate (@ max resolution) | 30 fps | 30 fps | 60 fps |
| Price | $30 | $25 | $27 |

Looking at all three choices, each camera module is compatible with our Jetson nano and could be utilized in our data collection process. Another similarity these components have in common is a max resolution of 1080p which would be sufficient for high-quality image capturing. The differences are in the field of view and frame rate. We ended up going with the IMX219-160 camera module based on the 160° field of view. This wider field of view allows for greater overlap between images, and it ensures we can create a better reconstruction with fewer images. Since the price points for each module are around the same amount, we decided there wouldn’t be a significant drawback to going with the pricier option.

1.5 Analysis of Component 5: Keypad

A keypad is a subtle but, nonetheless, important aspect of our design. It is the primary way for users to interact with the system.

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| --- | --- | --- | --- |
|  | Parallax 4x4 matrix membrane keypad | Sparkfun 12button keypad | Adafruit 4x4 matrix keypad |
| Dimension(mm) | 69x76x4 | 58x80x23 | 86x82x24 |
| Board Layer | Single Thin Flim Layer | Double Injection Layer | Double Injection Layer |
| Price | $9.27 | $4.95 | $5.95 |

For our keypad comparison, the emphasis is more on the mechanical construction itself, as the underlying mechanism for all three choices is the same. Choosing the best one that fits our final assembly design requires careful consideration of chassis support for the keypad. As such, the physical dimension is an important factor along with board layers.

Out of the three keypads, both Sparkfun [10] and Adafruit [11] have double board layers for additional structural rigidity. Nonetheless, it requires a thicker chassis with larger cutouts in order to house the keypad, and this makes our portable device bulky and a lot less convenient. The double layer construction also reflects the physical dimensions of the keypad, as both Sparkfun and Adafruit are substantially thicker than the Parallax keypad on the Z-axis.

As a result, we will use the Parallax 4x4 matrix keypad [12] since it will simplify and flatten out our chassis design, making up for its higher price.

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