1. 3. DESIGN APPROACH

Mr-r Mr-r strives to take in-house assistance to a new level of convenience by providing users with both useful and potentially life-saving information all from the comfort of their bedroom. The mirror was developed to offer guidance during the user's morning routine, using customized modules to give the user a personal and modern spin on the classic use of a traditional mirror. Along with modules to provide visual information to the user, the use of artificial intelligence gives the mirror a way to communicate audibly with the user. To reach the goal of creating a new at-home assistant, a few different designs for Mr-r Mr-r were brainstormed and considered after starting the initial research for the project. Throughout the design process, the group was able to find many requirements, standards, and constraints. The most important requirements the group found necessary for the success of Mr-r Mr-r, were the ability to have conversations with the mirror, provide a clear display that is easy for the user to understand, and the ability to use touchscreen. The biggest constraint for developing a project of this magnitude was making a working prototype in two semesters while staying under the budget of $1,000. Finally, International Electrotechnical Commission (IEC) Standard: Audio/Video, Information and Communication Technology Equipment — Safety Requirements, was referenced to set the standard of incorporating protective circuits and insulation that would prevent electrical hazards during extended usage of the mirror. The following subsections show the design choices made while creating Mr-r Mr-r and detail how it meets the requirements mentioned above.

3.1. Design Options

For the design approach, the team evaluated two distinct solutions for the Mr-r Mr-r smart mirror implementation. The first approach centered on a compact vanity mirror design, leveraging the traditional form factor to enable versatile mounting options. This solution would require external casing and power infrastructure, making it dependent on additional components for full functionality. While this design would benefit from extended user interaction periods typical of vanity mirror usage and maximize AI integration opportunities, it presented several technical challenges. The limited display area created a fundamental conflict between mirror functionality and widget visibility, potentially compromising the core mirror experience. Additionally, the infrared touchscreen technology proved vulnerable to moisture interference, particularly problematic in bathroom environments where steam and condensation are common.

The second design approach evolved toward a larger standalone display format comparable to television dimensions. This solution addresses many limitations of the vanity mirror design while introducing new capabilities. The increased screen real estate significantly improves module visibility and touchscreen accuracy, eliminating the need for users to strain to view displayed information. By positioning the unit outside bathroom environments, this design circumvents moisture-related challenges that could affect touchscreen functionality and display visibility. The standalone nature of this solution also simplifies installation and eliminates the need for complex mounting systems. While this approach may sacrifice some convenience for traditional vanity mirror use cases, it provides a more robust and reliable platform for delivering the core smart mirror functionality and interactive features of Mr-r Mr-r.

3.1.1. Design Option 1

One design option the group considered was creating a small vanity mirror. The mirror was going to be the normal size of a vanity mirror so that it could be placed in a variety of different mounts. The smart mirror would not be stand alone and would need external casing to work as intended. For this to work, the group would need to also create an enclosure that would hold this vanity mirror as well as provide all the necessary power sources to plug up all the different parts.

One benefit of this design would be that Mr-r Mr-r is best utilized in an area where the user spends a lot of time in the same vicinity as the mirror. The mirror has many great widgets as well as AI integration that would help with a range of daily tasks if used properly. Since vanity mirrors are often used for long periods of time, this would optimize the time between Mr-r Mr-r and the user. However, because the smart mirror has widgets that are displayed on the screen it would be difficult to display these modules while also giving the user enough space to still have the mirror effect. Since Mr-r Mr-r is advertised as a mirror, this needs to be the focus of the project. If the user cannot see themselves due to the number of modules on the screen, then this is an issue. Another limitation is that the touchscreen Mr-r Mr-r utilizes is infrared. Because of this, the steam from showers and sinks could interfere with the touchscreen aspect of the mirror. Touchscreen is an essential part of Mr-r Mr-r because this allows the user to customize the screen however they want. To avoid this, a design that better fits what Mr-r Mr-r is meant to achieve was considered.

3.1.2. Design Option 2

The design that has become the prototype design for Mr-r Mr-r is one that includes a bigger display, rather than a vanity unit where the mirror could be placed inside. Mr-r Mr-r needed to be a standalone unit, sized closer to a television rather than one of a tablet or laptop screen. Benefits of a larger screen include being able to clearly see the modules displayed on the mirror without having to strain the eyes to make out what is being displayed, and less room for error with the touchscreen. With a bigger area to touch on the screen, it would be clearer for the touchscreen to detect where the mirror was being touched. Being that Mr-r Mr-r has different electrical components, removing the unit from a bathroom or lavatory location became a clear path for the success of the mirror. Taking Mr-r Mr-r away from the bathroom also takes it away from potential errors from that location including the mirror fogging up, making the display difficult to see, condensation causing errors with the touchscreen, and problems with audio input due to loud sounds like running water which would hurt the mirror’s ability to hear the user. Therefore, this is the more attractive option.

3.2. System Overview

At its most basic level, Mr-r Mr-r is an AI-integrated smart mirror that takes in user input through either speech or touch and responds with visual or audio output. Figure 3-1 shows a basic black box diagram of how Mr-r Mr-r functions. The device operates with a 120 VAC power supply and uses a combination of sensors and a display system to interact with the user. Once powered, Mr-r Mr-r listens for spoken commands or detects touch input, processes the data internally, and delivers a response either through its screen or built-in speaker system.

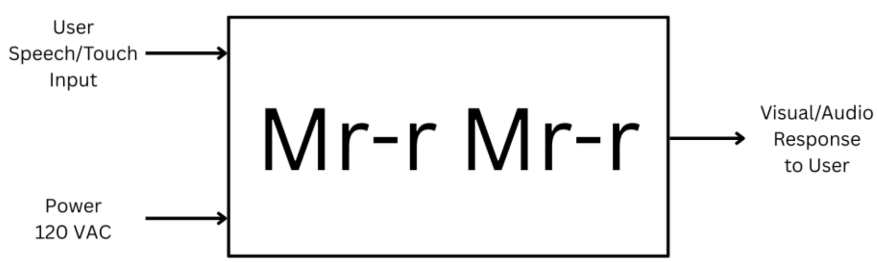

Fig. 3-1: Mr-r Mr-r System At A Glance (Level 0)

Figure 3-2 shows a more detailed functionality of Mr-r Mr-r and how each of its subsystems interact with each other.

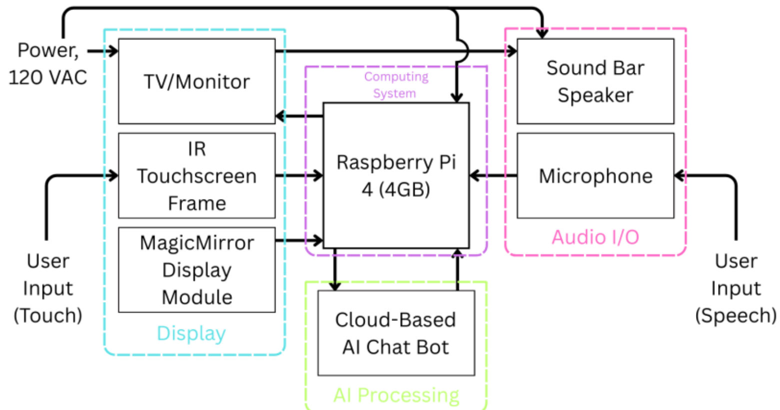

Fig. 3-2: Mr-r Mr-r Functionality (Level 1)

Mr-r Mr-r is designed to function independently, with the main user inputs being either voice commands or touch interaction with the screen. The internal subsystems work together to process these inputs and deliver a response. The display subsystem presents information visually and allows user interaction through a touchscreen overlay. The computing system coordinates data processing and communication between all modules. Audio input and output are handled by a lavalier microphone and sound bar, respectively. Cloud-based AI services enable advanced features such as speech recognition and response generation. All subsystems are connected and controlled through the Raspberry Pi to ensure seamless performance.

3.2.1. Microcontroller

For Mr-r Mr-r's AI and computing systems, several different microcontrollers were considered based on their computing ability, operating system, and price. Table 3-1 shows the specifics of each device considered.

Table 3-1: Microcontroller Options

Processor	RAM (GB)	Clock Speed (GHz)	Price ($)	Operating System	Community Support
Requirements	4	1.5	< 100	Linux	Heavy
Raspberry Pi 4 Model B [1]	4	1.8	63	Linux	Heavy
Jetson Nano [2]	4	1.5	224	Linux	None
Lenovo ThinkCentre M700 [3]	8	3.2	80	Windows 10	Limited

The Raspberry Pi 4 Model B was chosen as it best fit the needs required of Mr-r Mr-r. It was chosen for its ability to handle running multiple programs at once using Linux, array of output functionality, and its heavy support from the community. Figure 3-3 presents the selected microcontroller.

Fig. 3-3: Raspberry Pi Model B Microcontroller [1]

To fulfil the needs presented by the Mr-r Mr-r, the microprocessor needs to be powerful enough to support running multiple software systems operating and communicating with each other at once, equipped with Wi-Fi capabilities to ensure the computer-to-cloud communication necessary for running the AI systems. It also needs to support an operating system with minimal pre-built functionality to ensure rapid execution of programs, and it needs to be full of community support so extra programming resources could be accessed. The Raspberry Pi 4 Model B was the most equipped and most cost-effective option. With 4 GB of memory, a clock speed of 1.8 GHz, and WiFi capabilities, the Raspberry Pi 4 Model B is more than powerful enough to handle the smart mirror software as well as support the AI communications necessary for the mirror to run smoothly. With a Linux based operating system, the Raspberry Pi should execute programs swiftly with minimal lag due to preloaded softwares. Furthermore, Raspberry Pi developers share many of their projects and the programming tools used to develop those projects, meaning developing programs for the Raspberry Pi is significantly easier than programming with other microprocessors. The Raspberry Pi also sports multiple USB connections and an easy-to-access Micro-SD card which allows for the support of multiple connections, and thus devices, at once. Overall, while some microprocessors are more powerful, the Raspberry Pi meets the required needs at a cost-effective price with minimal preloaded software compounded with extensive community support. Because of these factors, the Raspberry Pi 4 Model B was chosen as the microprocessor for Mr-r Mr-r.

3.3. Subsystems

The design for Mr-r Mr-r is divided into four unique subsystems. These high-risk categories are listed as follows:

2. The display subsystem provides clear visuals while maintaining the functionality of a traditional mirror.
3. The AI processing and communication subsystem is a customized AI model that enables natural and dynamic conversational responses.
4. The audio input and output subsystem provides seamless communication with the AI that is built into Mr-r Mr-r.
5. The computing system serves as the core processing unit responsible for handling all AI functions and display management.

3.3.1. Display

The display subsystem provides a clear visual representation of a modified MagicMirror interface with customizable widgets. It makes use of a 32-inch OLED television, which serves as the primary visual output device. An acrylic two-way mirror sheet is mounted to the surface of the screen, allowing the device to function as a standard mirror while the device is in use. Table 3-2 details each option considered.

Table 3-2: Display Options

Display Output	Resolution	HDR (High Dynamic Range	Panel Technology	Price ($)
Requirements	$\leq$ 1080p	Yes	LED	< 200
Samsung 32” Class N5300 [4]	1080p	Yes	LED	169.99
FPD 32 Inch Smart TV [5]	720p	No	LED	149.99
Samsung 32 Inch Class H5000F [6]	4320p	Yes	OLED	239.99

Figure 3-4 shows the chosen television for the implementation of Mr-r Mr-r’s display.

Figure 3-4: Samsung 32" Class N5300 [4]

To enable user interaction, a 32-inch, 10-point infrared touch frame is overlaid on top of the mirror film. This touch frame detects input by sensing interruptions in the infrared emitters and sensors surrounding the frame's perimeter. The use of infrared technology allows for multi-touch input without requiring direct pressure on the screen, offering a more responsive and intuitive user experience.

Table 3-3: Mirror Options

Mirror	**Reflective**	**Mirror Type**	**Price ($)**
Requirements	Yes	Any	< 120
See-Thru / Two-Way Mirror Acrylic Sheet [7]	Yes	Acrylic Sheet	110.25
SupremeTech See-Through Two-Way Mirror [8]	Yes	Tempered Glass Mirror	124.99
Infinite Two Way Mirror Film [9]	Yes	Mirror Film	19.20

Figure 3-5 shows a sample image of the acrylic two-way mirror sheet chosen to be mounted onto the display.

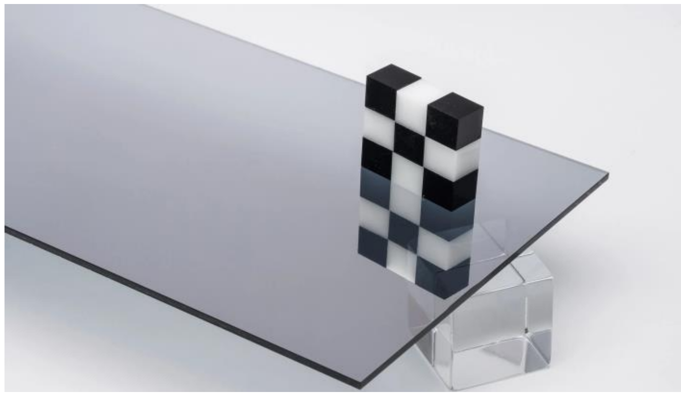

Figure 3-5: See-Thru / Two-Way Mirror Acrylic Sheet [7]

The television is powered directly via a standard 120V AC wall outlet. The touch frame is powered and controlled through a USB interface connected to the Raspberry Pi, which serves as the primary processing unit for Mr-r Mr-r.

The layered construction of the display-television, acrylic film, and touch frame ensures a seamless blend of reflective functionality and interactive digital output. The infrared frame's external mounting allows for easy maintenance and replacement without affecting the underlying display or mirror layer.

3.3.2. AI Processing

The AI processing subsystem creates a variety of potential uses for the user. It creates an opportunity for users to have a conversation with the device, similar to other home assistant products. Table 3-4 details all AI options considered.

Table 3-4: AI Options

Model	**Cost ($)**	**Setup Complexity**	**Response Time/Accuracy**
Requirements	Free	< High	Rapid and accurate
Hugging Face Inference API [10]	Free tier available	Medium	Slow and inconsistent
Snips.ai [11]	Free (not available anymore)	High	No longer maintained
ChatGPT Plus [12]	5/Million Tokens	Medium	Rapid and accurate
Rhubarb Lip Sync [13]	Free	Medium	Untested

In the brainstorming process, the team considered several potential AI options for the mirror. After thorough research, ChatGPT Plus with OpenAI's GPT-4 Turbo (mini) emerged as the superior choice for our implementation. While initial concerns about subscription costs were valid, the exceptional performance and reliability of GPT-4 Turbo ultimately justified the investment for the Mr-r Mr-r project.

The OpenAI API integration sends voice input directly to the GPT-4 Turbo model, which processes the text and generates remarkably natural, contextually aware responses—displayed in real-time on the mirror. During testing, the difference in quality became immediately apparent: GPT-4 Turbo consistently produced more coherent, helpful, and human-like responses compared to alternatives.

The GPT-4 Turbo API was selected for integrating AI into the MagicMirror's Hive module primarily due to its superior performance in conversational contexts. OpenAI's platform offers state-of-the-art language understanding and generation capabilities, enabling features like complex question answering, personalized recommendations, and nuanced, responsive interactions. Its straightforward API ensures minimal latency and robust handling of diverse user queries, making it ideal for a responsive and engaging interface within the MagicMirror environment. Although it requires a subscription, the quality-to-cost ratio makes it a worthwhile investment for a production-ready implementation, ensuring consistent, high-quality interactions that enhance the user experience.

While we initially explored alternatives like Hugging Face's Inference API, testing revealed significant limitations in response quality and consistency. Hugging Face models frequently produced repetitive or nonsensical outputs and struggled to maintain coherent conversations—a critical requirement for our voice-activated mirror assistant. Additionally, the setup process was more complex than expected, with frequent compatibility issues and model-specific errors that hindered development progress.

In contrast, the GPT-4 Turbo API delivered immediate, reliable results with minimal configuration, allowing the team to focus on refining the user experience rather than troubleshooting technical issues. Its superior natural language understanding, context retention, and overall response quality ultimately made it the only viable choice for realizing the seamless, intelligent interaction envisioned for the Mr-r Mr-r project.

3.3.3. Audio Input and Output

The audio input and output subsystem creates a way to communicate with the AI without the need for physical interaction from the user. This subsystem makes use of a microphone that is powered by a 5V DC supply and a speaker that plugs into a 120V outlet. The microphone will connect to the Raspberry Pi by USB and the speaker will connect through an optic connection.

The microphone is meant to take speech from the user and transmit the audio to the Raspberry Pi where it can convert the speech to text. Because the speaker needs to isolate voices and have noise canceling capabilities, only certain microphones could be used. The microphone also had to be compatible with the Raspberry Pi.

Table 3-5 shows the microphone options considered for Mr-r Mr-r. The microphone must be noise-cancelling, have a USB plug in for the Raspberry Pi, and be able to receive Hz of over 100.

Table 3-5: Microphone Options

Microphone	Noise- Cancelling	USB Plug in	Frequency (Hz)
Requirements	Yes	Yes	>100Hz
Fifine USB Lavalier Microphone [14]	Yes	Yes	50 - 16k Hz
HyperX SoloCast [15]	Yes	Yes	Up to 96kHz
Movo LV1 Lavalier Microphone [16]	Yes	Yes	50 - 10kHz

Figure 3-6 shows the selected microphone from Amazon. The microphone provides all of the necessary requirements while being better quality for the price among the other options.

Figure 3- 6 Fifine USB Lavalier Lapel Microphone [14]

The speaker is meant to output the audio that the AI converts to speech. When the AI produces a response, the speech is sent through the speaker. The speaker needs to be able to produce a high sound level as well as be compatible with the Raspberry Pi. Because of this, only certain speakers could be used. Table 3-6 shows the speaker options that were considered for Mr-r Mr-r. The speaker needed to have an optical connection, be able to produce a frequency greater than 100Hz, and be under $60.

Table 3 -6: Speaker Options

Speaker	Optical Connection	Frequency	Price
Requirements	Yes	>100Hz	<$60
Wohome 2.1ch Sound Bar [17]	Yes	160kHz	$50
Creatie Pebble Pro Minimalist 2.0 Speaker [18]	Yes	200kHz	$56
Solution R60 Bluetooth Speaker [19]	Yes	20kHz	$40

Figure 3-7 shows Wohome 2.1ch Sound Bar. The speaker provides all the necessary requirements for the project while offering a higher-quality product for the price.

Figure 3-7: Wohome 2.1ch Sound Bar [17]

The speaker and microphone create a system that allows for seamless communication with the AI. The audio and output subsystem creates features in Mr-r Mr-r that have not previously been integrated with a smart mirror and thus makes this design new and unique.

3.3.4. Computing Systems

The computing systems for Mr-r Mr-r are tasked with operating software systems which receive multiple different inputs from physical sources and digital sources simultaneously and parse through them to output the user's request. These systems manage two physical inputs: audio (processed by the Fifine USB Lavalier Lapel Microphone) and physical registers (interacted via the GreenTouch IR Touch Frame). These physical inputs interact with the MagicMirror software, are processed accordingly, and the computing system outputs the user's desired request. Figure 3-8 shows a high-level visual depiction of this process.

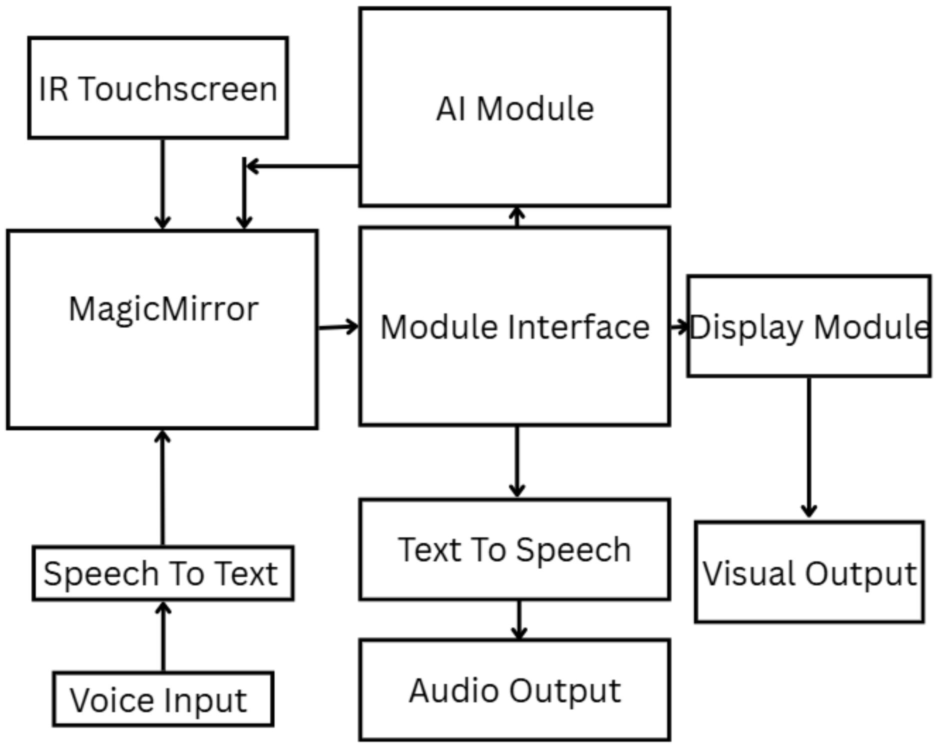

Figure 3-8: Computing Systems Diagram

Once the physical inputs are registered, they are sourced through the Raspberry Pi OS and filtered into the MagicMirror software. From here they are piped into modulation, in which the system of processing is determined. For example, interaction with the calendar module via the touchscreen will require the calling of the touchscreen scroll module in order for this process to work effectively. These two modules must work seamlessly together, made possible via the modified Magic Mirror software. Furthermore, the AI subsystem must also be able to interact with all these systems and make changes as needed. This can be done via voice control, requiring the implementation of a Python script which transforms speech to text. Utilizing PyAudio, this is a relatively simple procedure. This text is then fed into the AI module, which processes the text and decides what needs to be done based on the user's request. This creates the unique position of the AI being both an output system and a recursive input system—the AI needs the capability to interact with itself to fulfill the user's request. An example of this would be a voice command to modify the user's calendar. This would first be routed to the python script, then to the mirror modulation which would feed it to the AI Module, which would then interact with the calendar module before outputting a visual output—a calendar change—and an audio output stating the process was completed successfully. This requires another system within the AI module of text to speech, allowing for seamless communication between the user and the AI module. These computing systems all interact flawlessly with one another, allowing for rapid, error-free, high-level processes to be executed upon the user's request.

3.4. Level 2 Prototype Design

As a fully integrated prototype, the Mr-r Mr-r's components are contained in a hand-made wood housing unit as a single device that functions seamlessly. The housing will contain all three of the system's physical subsystems and their components. The housing will also contain an internal power strip so that only one connection to an outlet is required to power the device. Moreover, a two-way mirror acrylic sheet will be overlaid to give the device a mirrored effect.

3.4.1 Level 2 Diagram

Figure 3-9 shows the final prototype design for Mr-r Mr-r. Its functionality depends on the integration of specific hardware and software components. The display is made up of a 32" OLED TV fitted with a GreenTouch IR touch overlay, running the MagicMirror display module. A Raspberry Pi 4 serves as the central processor, connected to peripherals via USB and HDMI, and running the necessary operating system and drivers. The audio system includes a FiFine USB lavalier microphone for capturing voice input and a 2.1 channel sound bar for delivering responses. Cloud services handle AI processing, enabling the mirror to convert spoken words to text, generate appropriate replies, and speak them back to the user.

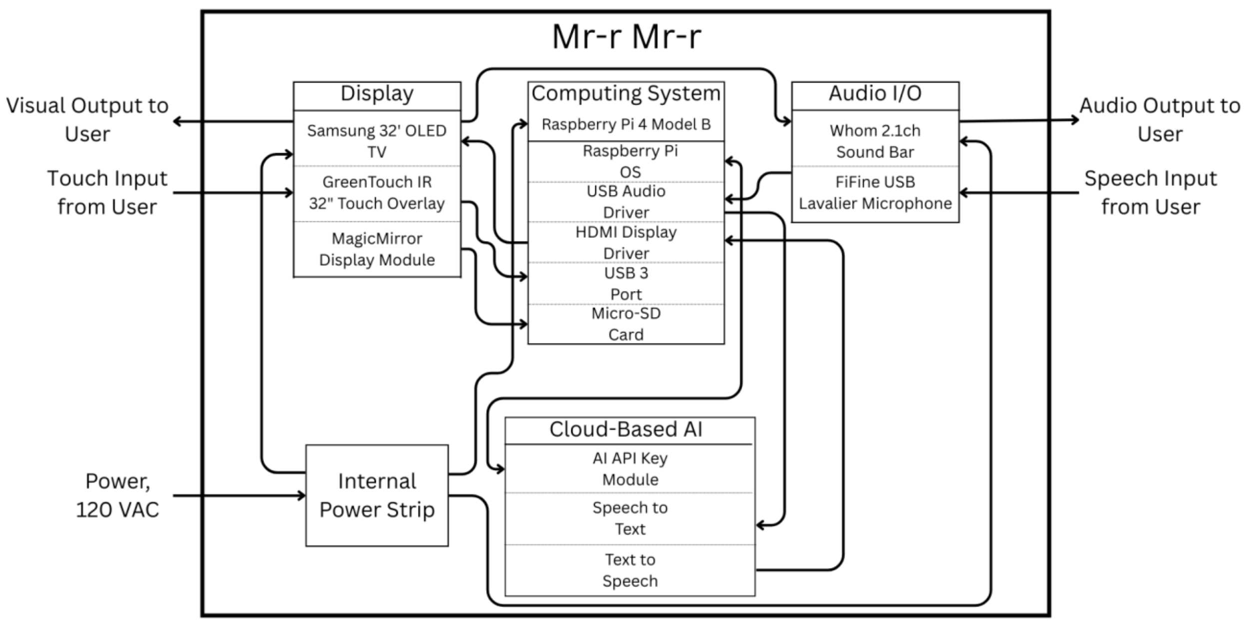

Fig. 3-9: Diagram for Mr-r Mr-r (Level 2)

The previous sections clearly and thoroughly outline the design approach for Mr-r Mr-r. In order for Mr-r Mr-r to function seamlessly, all subsystems must support each other and function as one singular device. However, to ensure this level of functionality could be achieved, these subsystems had to work individually before integration. The following sections describe the testing of these subsystems.

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