# Electronics Parts:

| Part name | Quantity | Recommended vendor | Price |
|---|---|---|---|
| MG955 servo motor | 2 | Robotshop.com | £12 |
| Raspberry Pi Zero W 2 | 1 | Raspberrypi.com | £17 |
| Raspberry Pi Camera module 3 | 1 | Raspberrypi.com | £26 |
| Pi Zero camera adaptor | 1 | link | £4 |
| GPIO header pins | 40 pins | Any electronics vendor | ~£0.5 |
| Momentary switches (3-way, toggle, to adjust servos) | 2 | link | £2 |
| Momentary switch (2-way, to capture image) | 1 | Any electronics vendor | £1 |
| Toggle switch (2-way) | 1 | Any electronics vendor | £1 |
| WS2812 (LEDs) | 10 | Any electronics vendor | ~£2 |
| 10000mah, 5V battery pack | 1 | Any electronics vendor, example | ~£20 |
| (Custom) Power distribution board | | | ~£2-5 |
| Total Price: | | | ~£90 |
| Jumper wires, solder, and other miscellaneous items may be required during assembly – but have not been included as exact quantities will depend on the final design & assembly procedure. USB and Display cables have not been included above for the same reasons. | | | |

Figure. 1

# Part Selection:

The particular parts chosen here were chosen as they are available at low-cost, supported extensively by open-source software libraries, available globally, and easy to implement and repair.

**Raspberry Pi Zero W 2:** Chosen as it is the best overall single-board computer that has built-in WIFI and enough computing power to capture an image. The Pi Zero 2 was chosen as it has a smaller footprint and is much cheaper than the regular Pi 4.

**Camera Module 3:** It is able to produce a high-quality image, has an in-built image processor, and is supported by a wide variety of software libraries. It is also relatively cheap and easy to procure globally.

**MG995 Servo Motor:** It is very cheap in comparison to other motors, whilst having sufficient torque and an-inbuilt encoder for precision control. It does not require an external driver in most cases, reducing the overall system cost.

**WS2812 LEDS:** These LEDS are individually addressable via a signal wire, but can be connected in series and this require only 3 wires to the Raspberry Pi. They have sufficient brightness and do not require an external driver for under any segment under 20 LEDS.

**5V battery bank:** A 10,000mah capacity battery bank was chosen as it can provide approximately 1 day of battery power for the entire system, whilst balancing weight and system. It is convenient to use a pre-built battery bank as it includes charging circuitry, and most can provide the 2.5A (peak) needed for the entire system.

**Power distribution board:** The use of a basic power distribution board (which may have to custom designed) is proposed, to provide safe and reliable power distribution for the device. It would take in power from the battery

bank (via USB), and then output it to the servo motor, Raspberry Pi and other 5V devices (LEDs, etc.). It would contain circuitry that would filter the power before sending it to the Raspberry Pi, such that any back EMF from the motors would not damage the Raspberry Pi. Such boards can be found online, or can be custom fabricated using low-cost PCB suppliers. The use of off-the-shelf IC's and through-hole components would lower the cost and allow for easier repairability in remote locations. Due to the limited duration of the project, we were unable to design the PCB for such a power distribution board, but it is something that is highly recommended when future work is carried out on this project. Overall, it will be a simple, straightforward and cheap PCB to design and manufacture.

## Battery Life estimation:

The calculations below were used to calculate an estimate of the systems battery life. It takes the following assumptions:

- 12 hours of use in a day, where actual scanning of eyes occurs for 6 hours. This is reasonable as time will be taken to register patients, inform them about the procedure, and perhaps offer them an initial diagnosis
- We have assumed that the servos use ~300mA when operational. This is based on a peak stall torque of 1200mA, and we will require less than half of the motor's maximum torque during operation. Furthermore, in most cases the servos will be making very small adjustments, and will be idle most of the time.
    - o We can therefore assume that the motors draw current for approximately 3 hours of the day
- For the Raspberry Pi, 6 hours of runtime is assumed, with the camera and WIFI network on at all times
- All other current draw values are obtained from the respective component's datasheet.

Total current draw = 1200mA (Raspberry Pi) + 50mA (LEDs) + 300mA (motor) ~ 1.5A

10000maH = 10 aH

Battery life = 10/1.5 ~ 6+ hours

Therefore, the device will work for 6+ hours a day, fulfilling the design requirements. Our assumptions over-estimate the current draw of the components, meaning we can expect closer to 8+ hours a day of operation in most cases. Climate conditions and lifetime wear may reduce the effective capacity of the battery over time. Furthermore, the use of a battery bank means that it is easy to replace if it runs out.
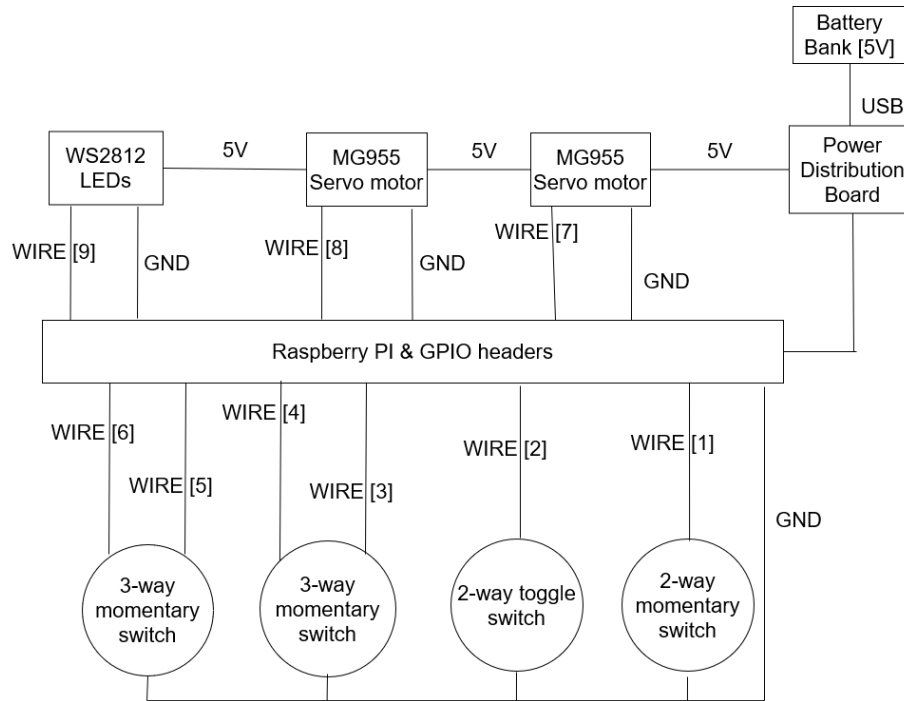
# Wiring Diagram and assembly:



Figure. 2: Wiring block diagram

A list of where each wire should be connected is included below. It is recommended that a jumper cable with a female header (see Fig 3) is used to connect the RasPi's GPIO pins, as this allows for changes to be made easily. When the final assembly is complete, it is recommended to apply a small amount of hot glue (or other electrically insulating, easy-to-remove adhesive) to ensure that vibrations do not cause the jumper cables to fall out. All other connections should be soldered, as this provides a secure electrical and mechanical connection.



Figure. 3

| Wire number: | Raspberry Pi: GPIO pin number (BCM coding) |
|---|---|
| Wire [1] | 5 |
| Wire [2] | 6 |
| Wire [3] | 13 |
| Wire [4] | 19 |
| Wire [5] | 26 |
| Wire [6] | 12 |

| Wire [7] − servo signal wire | 16 |
|---|---|
| Wire [8] − servo signal wire | 20 |
| Wire [9] − WS2812 signal wire | 21 |

Figure. 4: Suggested wiring guide

**3-way momentary switches:** Used for adjusting each lens forward/backwards respectively.

**2-way toggle switch:** Used to control the LED lighting ring.

**2-way momentary switch:** Used to trigger a manual image capture.

## Protecting against vibrations and water/dust damage:

To protect the Raspberry Pi from water damage, it is recommended that is covered with a conformal coating, which can be bought at most electronics/hardware retailers. It is used to provide a small amount of water-resistant as it is a hydro-phobic coating.

Additionally, the mechanical design should be created such that water never flows over the switches in the event that the device gets wet. This can be done by including ridges that break the surface tension of water, which allows it flow along surfaces at acute angles. However, the switches chosen are water-resistant, ensuring the electronics are protected in either case.

## Future improvements:

- Implementation of a PCB for power distribution
- Use of a DIY Li-Ion battery pack for higher energy density and cheaper cost
    - Time-consuming to design, so we opted to use a battery pack for the initial prototype design
- Improved vibration protection by mounting the Raspberry Pi and other electronics on a vibration dampening assembly or using rubber O-rings
- Further testing of the components to determine their true water/dust resistance
- Using a cheaper, lower-resolution camera − if testing shows that a lower-resolution image is sufficient to image the fundus thoroughly
- Using servo drivers to increase servo output power, if the Raspberry Pi is unable to drive them to their full capacity