Rodent Rotation and Translation Stage (RRaTS)

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Abstract

Ophthalmology research often requires the viewing of photoreceptor cells in the back of the eye. In order to successfully image the subject's photoreceptors, the eye of the subject must be rotated about two axes. Traditional stages for microscopic viewing provide easy solutions for translational movement but lack the features necessary to rotate while keeping focus on the subject. Our client desires a device which can provide rotational movements around two axes and translational movements in all three dimensions. Different sized subjects will need to be viewed on the device without compromising its movements or accuracy. The final device shall concentrate on increasing the possible motion while keeping the center of all rotations focused on the pupil of the subject.

Background

Research and Biological Background

- Glaucoma, macular degeneration, and other degenerative ocular diseases, can indicate risk for cardiovascular disease and diabetes [1].
- Before reaching the retina, light passes through four primary components: the cornea, the pupil, the lens, and the vitreous body. Then the light passes through the 10 layers of the retina, which includes a layer of photoreceptor cells (rods and cones).[2]
- Researchers use a TMC vibration isolation table (Figure 2) to keep subjects stationary.

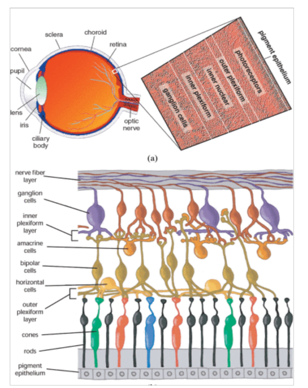


Figure 1. An expanded view of the retina and respective photoreceptors of a human eye. [2]

Design Background and Motivation

- Goal of our design: Aid in imaging the retina located in the back of the eye in relation to the pupil.
- Sample rotation in relation to the imaging device are required to successfully view and image all the photoreceptors of the eye

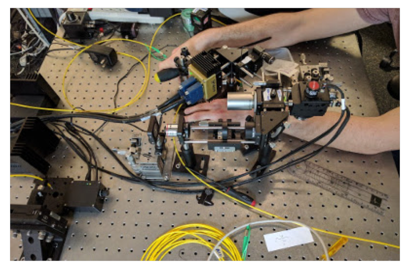


Figure 2. A horizontal facing microscope on a vibration-less table in Rogers Lab [3]

Competing designs

Gyroscope

•Double Axle gimbal mount, which independently rotates about each axis

•Maintains a constant center of rotation

Figure 3. A visualization of 3-axis rotation of a gyroscope. [4]

Modular motion stages utilizing interconnecting elements

- Device contains interlocking elements for modular device.
- First modular device allows for translational movements
- Second modular device allows for rotational movements
- Third modular device permits multi-axis linear-rotational movements
- This device gives the option of modular pieces that was of interest to our client

Keyence Digital Microscope

- Digital microscope that can capture pictures in real time with 2D measurements.
- Allows for high tech pictures paired with measurements capabilities.
- Device does not accomplish the cost specification.

Figure 7. An image of the Keyence device, including the imaging device and the viewing screen. [6]

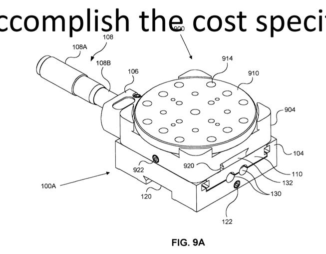


Figure 6. A diagram for the third modular device for multi-axis rotational movement. [5]

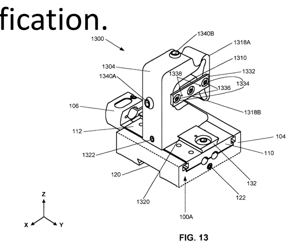


Figure 5. A diagram for the second modular device for rotational movement. [5]

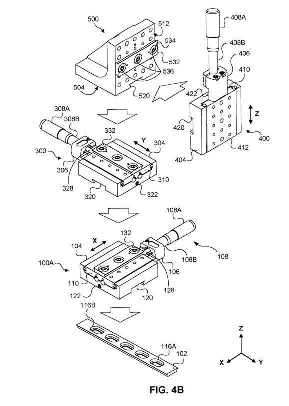


Figure 4. A diagram of the first modular device for translational movement. [5]

Problem and Aims

Problem:

- Current microscope stages cannot rotate and translate about the subjects' pupils in an accurate or ergonomic manner within the price limit

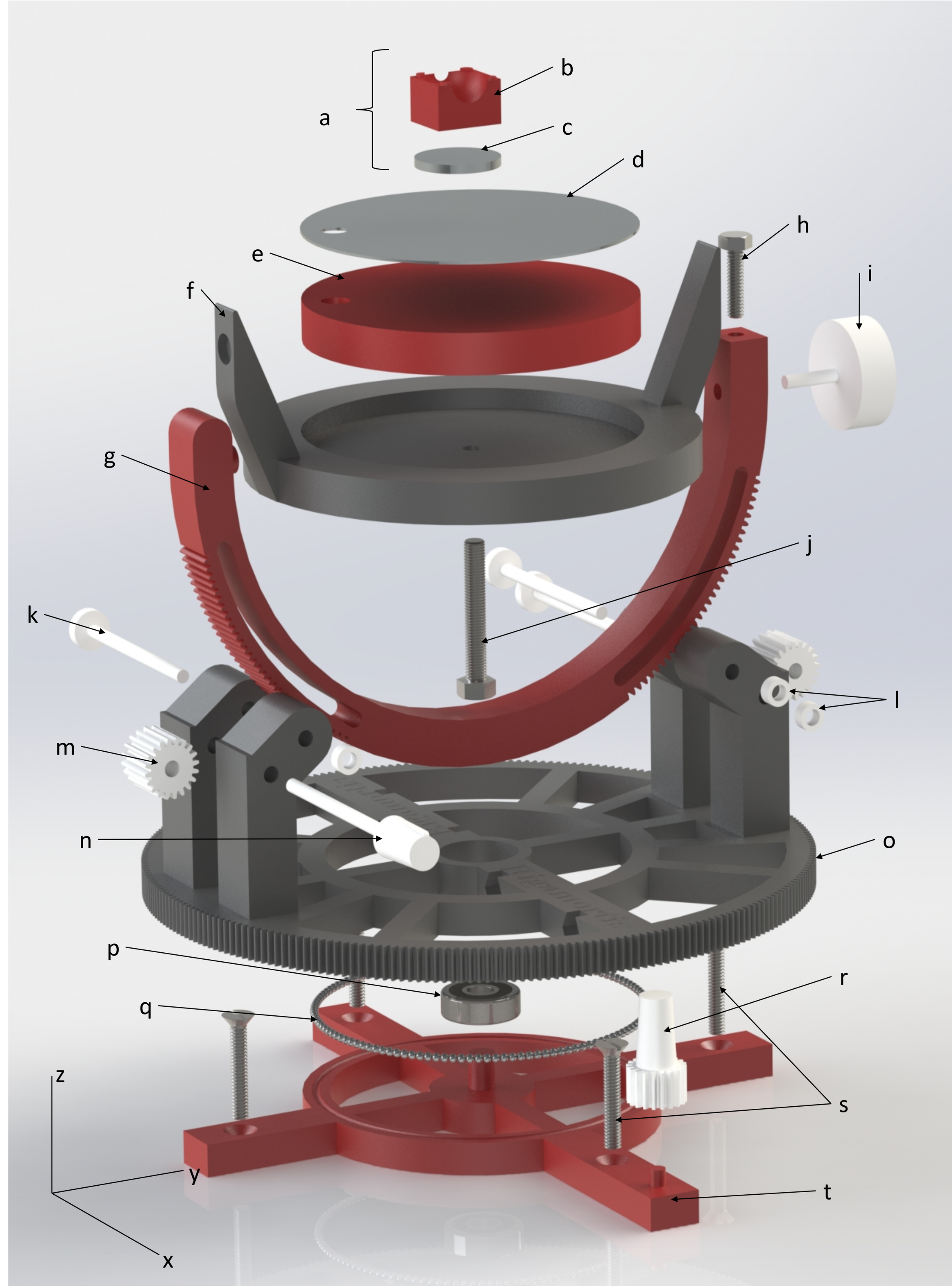
Project Goal:

- Design and manufacture a new microscope stage that can rotate and translate different rodent subject's pupils to aid in the viewing and image capture of photoreceptors.

Design Specifications

- At least 5 degrees of freedom
- 100 micron of translation precision
- 1 degree of rotational precision
- Modular specimen holders
- No larger than 30 cm x 30 cm x 50 cm
- Support 3.0 kg load
- Sterilizable with alcohol wipes
- Operate between -10° and 50° C
- Non-absorbable for water
- Under $250

Final Design



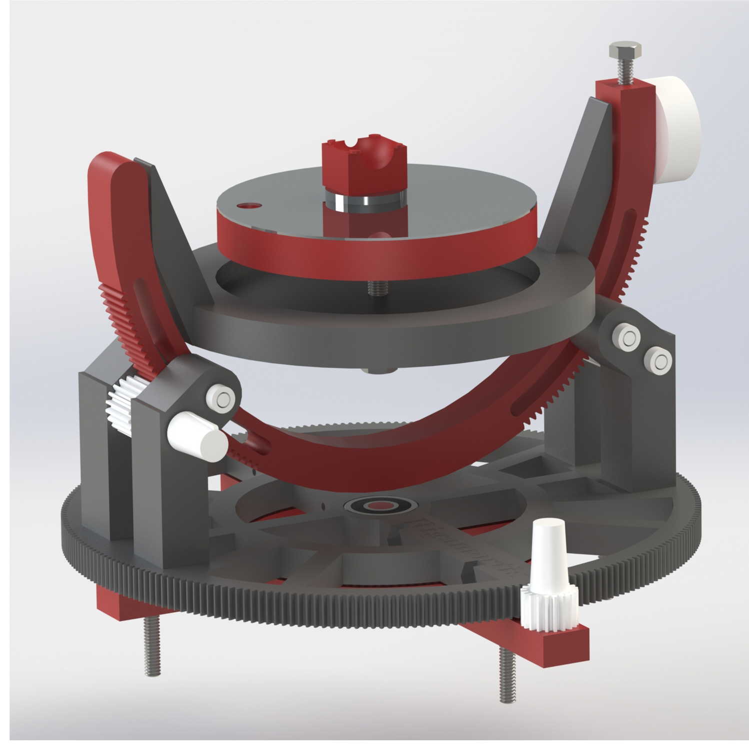


Figure 8 (above): SolidWorks model of our final design

Figure 9 (left): Exploded view of the final design containing the following components: **(a)** A replaceable modular device for holding a detached human eyeball made from a PLA holder **(b)** and a magnet **(c)**. The magnet is attached to a metal plate **(d)** which allows the eyeball holder to be easily translated in the x and y directions. The metal plate is attached to a plastic base **(e)** that sits above the swinging table **(f)**. This table enables rotation about the y-axis by rotating about its attachments to the support guide **(g)**. It is secured by tightening the bolt **(h)** after turning the adjustment knob **(i)**. The height of the eyeball can be adjusted using the bolt **(j)** which screws through the swinging table and into the circular plastic base. Support rods **(k)** hold the support guide above the rest of the device and are secured by caps **(l)**. Two gears **(m)** allow the device to be rotated around the x-axis when the knob **(n)** is turned. The entire device is rotated around the z-axis via its gear teeth **(o)**. This rotation is assisted by a needle bearing **(p)** and ball bearings **(q)**. Knob and gear **(r)** are turned by the user to control the z-axis rotation. Lastly, four screws **(s)** are screwed through the base **(t)** to secure the device to the vibration-less lab table.

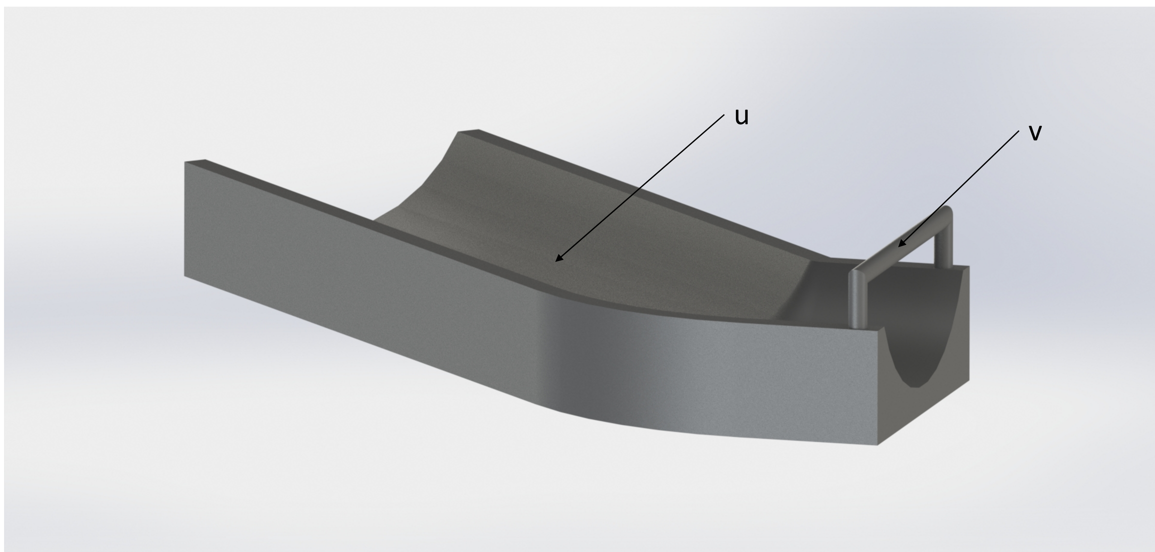


Figure 10 (bottom-left): In addition to the eyeball holder, there is another module device which is designed to hold a lab mouse or thirteen-lined ground squirrel. This holder features an angled trough **(u)** where the animal lays, and a cylindrical bite bar **(v)**. The incisors of the rodent are laid over the bite bar to stabilize its head.

Methods and Testing

Angular Test

- A digital inclinometer angle gauge was used to measure the range of angle rotation about the x and y-axis.
- The angle at the focal point was rotated with the gear or the knob. The angle was remeasured to track how precise the angular translation movement was.

Translation Test

- A sheet of paper was placed over a metal bar to track the increment of translational movement of our modular device.
- Holes punched by pins were used to track movement precision.
- A digital caliper was used to measure the distance between pin punches in micrometers.

Height Test

- A standard ruler with millimeter precision was used to measure the range of z-translation for the center rotating table

Ergonomics Test and Survey

- Users were introduced to the device and its function paired and given an overview of relevant background information
- A brief survey of ten questions concerning ergonomics was given to each user.
- Survey participants were procured from labs in WIMR on a volunteer basis

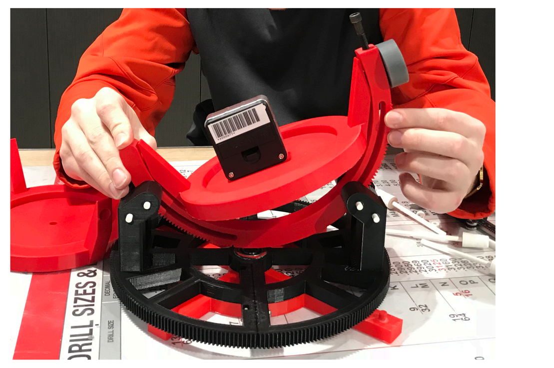


Figure 11: Angular test in progress

Figure 12: Height test procedure in progress

Discussion of Results

Mechanics of the Adjustment Knob (Max Stress Point)

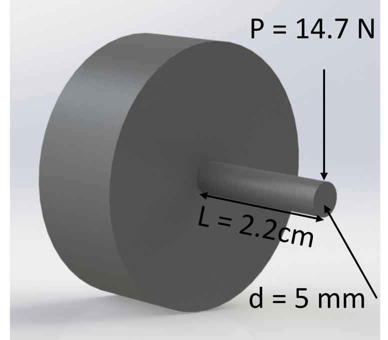


Figure 13. Mechanical diagram of knob

$$I = \frac{\pi r^4}{4} = 3.067 \times 10^{-11}\ m^4$$

$$M = PL = 0.3234\ N \cdot m$$

$$Q = \frac{2r^3}{3} = 3.07 \times 10^{-11}\ m^3$$

$$t = 2\sqrt{r^2 + \left(\frac{4r}{3\pi}\right)^2} = 0.00453\ m$$

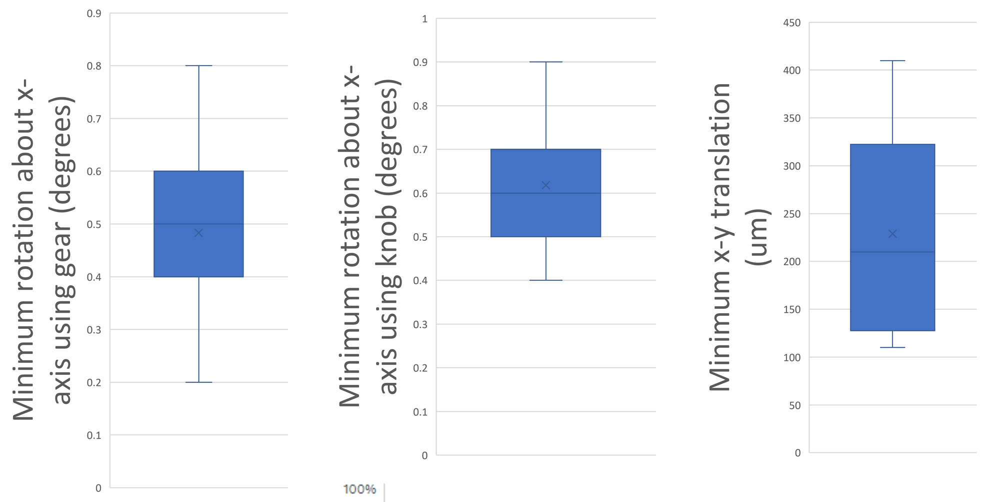
$$\sigma = \frac{Mr}{I} = 26.35\ MPa$$

$$\tau = \frac{PQ}{2rI} = 4.7\ MPa$$

Cured Grey Pro has an Ultimate Tensile Stress of 61 MPa [7]

$$\therefore f.o.s. = \frac{61\ MPa}{26.35\ MPa} = 2.31$$

Figures 14 – 16 (right): These box and whisker graphs shows statistical data for the minimum rotational and translational movements a user could make (minimum 10 trials).



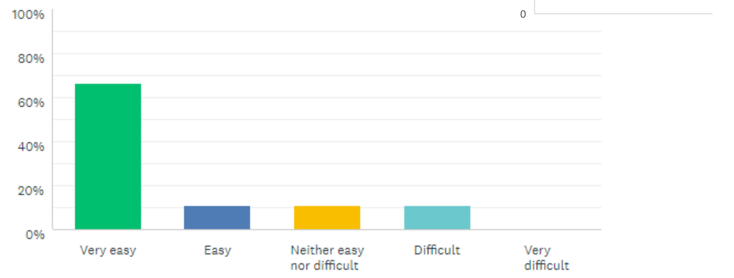


Figure 17. Ease of z-axis translation

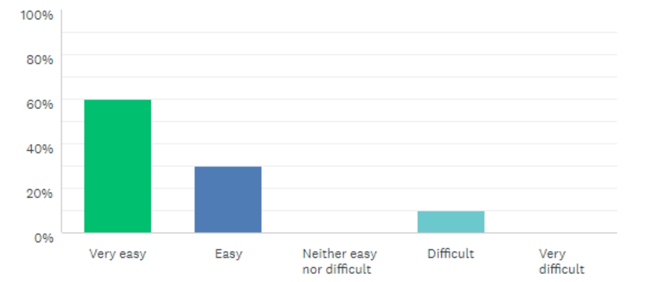


Figure 18. Ease of y-axis rotation

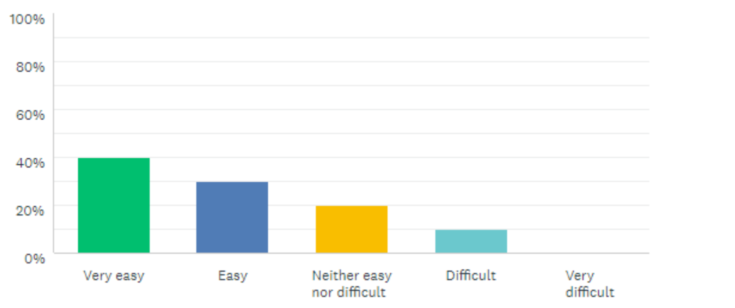


Figure 19. Ease of z-axis rotation

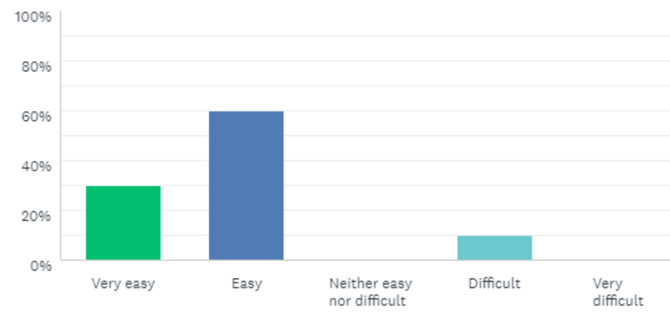


Figure 20. Ease of x-axis rotation

Future Work

Modifications to the Device

- Choose a stronger material for the dial to improve the factor of safety
- Improve the spacing between parts for smoother connections
- Modify specimen holder to accommodate a warming pad
- Increase ball bearing size
- Replace the needle bearing with a size 6200 ball bearing
- Improve the connection between the x-axis rotation gear and the knob shaft
- Increase the stability of the center table by adding a more durable bolt and nut modulation
- Change the center of the circular table to a stronger material than plastic for more precise movement and durability along the threads
- Add an arm on to the specimen holder so the specimen doesn't fall out.

Acknowledgments

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