Foveators: Strabismus correction with Risley prisms

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Motivation

- Strabismus (misaligned eyes) affects 5% of people[1]. It can be present in infancy or acquired later. It causes vision loss and destroys stereoacuity (depth perception).

- Current treatment options are[1]:
  1. Surgery: risky and usually not 100% effective
  2. Corrective lenses: fixed, work well only near center of vision
  3. Vision therapy: effective, but difficult, time-consuming, and expensive

- Goal: improve treatment with optical and computational techniques: Risley prisms (**Fig. 1**) and eye tracking (**Fig. 3**)

Methods

1. Create computer-controlled, mechanically actuated Risley prisms
2. Use existing eye-tracking system[2] to find gaze positions, control prisms
3. Use Maxwell's spot (see below) and eye tracker to localize fovea (**Fig. 2**)
4. Run user trials in strabismus patients to test for improved vision and stereoacuity

- Maxwell's spot is a dark splotch that appears in the visual field at the position of the fovea when a particular light stimulus is presented to the subject[3]. The subject can move a cursor to the perceived position of the spot to record its coordinates.

Figures

Figure 1 (above). Risley prisms are two wedge prisms coupled back-to-back. They can deflect light in any direction by angles up to ~20°. *Source: [4]*

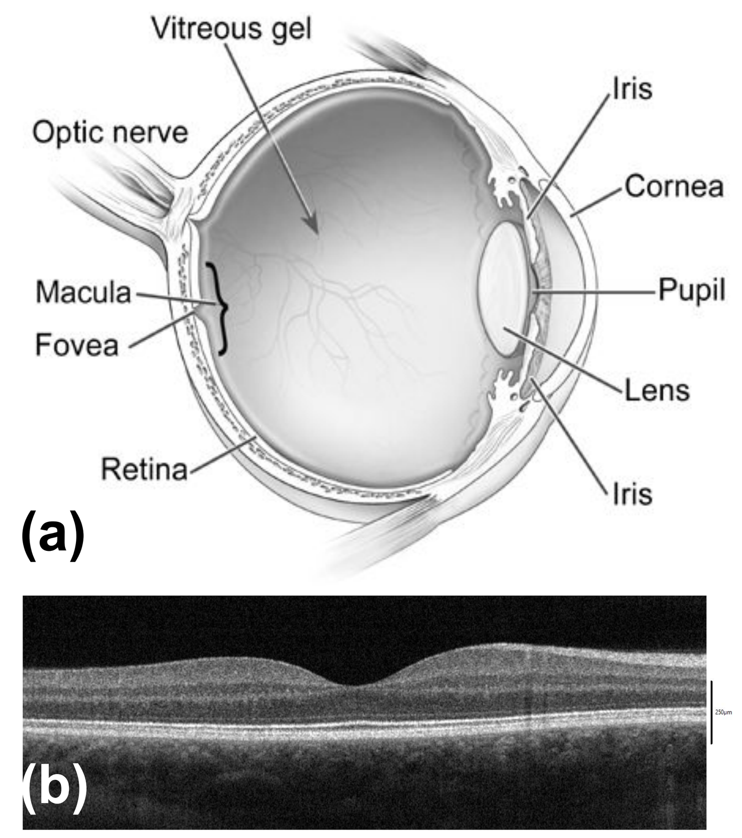

Figure 2 (right). ***(a)*** The fovea has the highest density of photoreceptors of any place on the retina, and provides the sharpest detail to the center of the visual field. ***(b)*** The foveal pit in cross-section. *Source: NIH*

Figure 3. The eye-tracker used to calibrate Risley prisms and localize Maxwell's spot. *Source: own work, [2]*

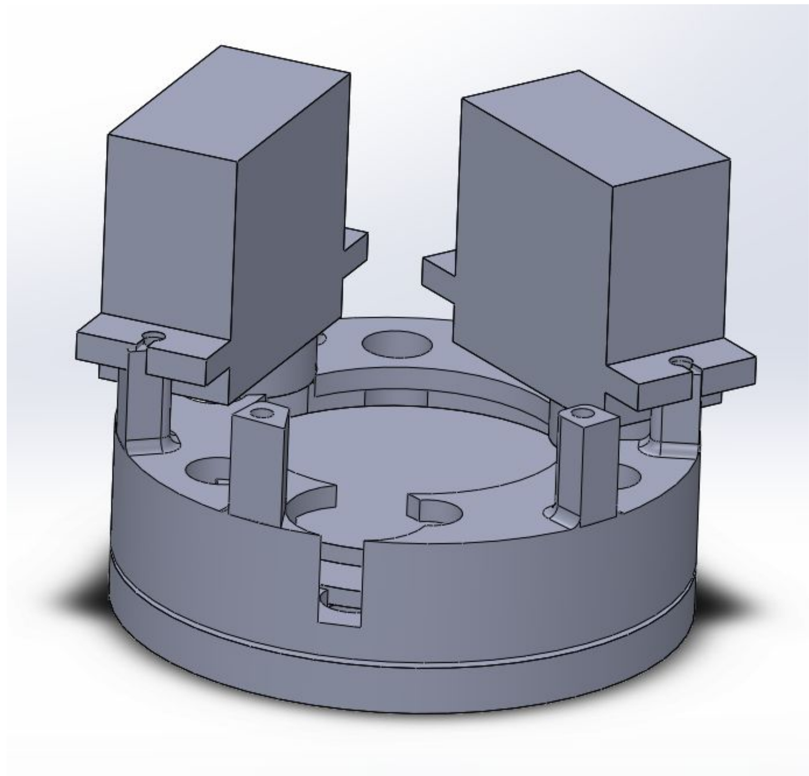

Figure 4. A SolidWorks model of the Risley prism assembly with servos attached. *Source: own work*

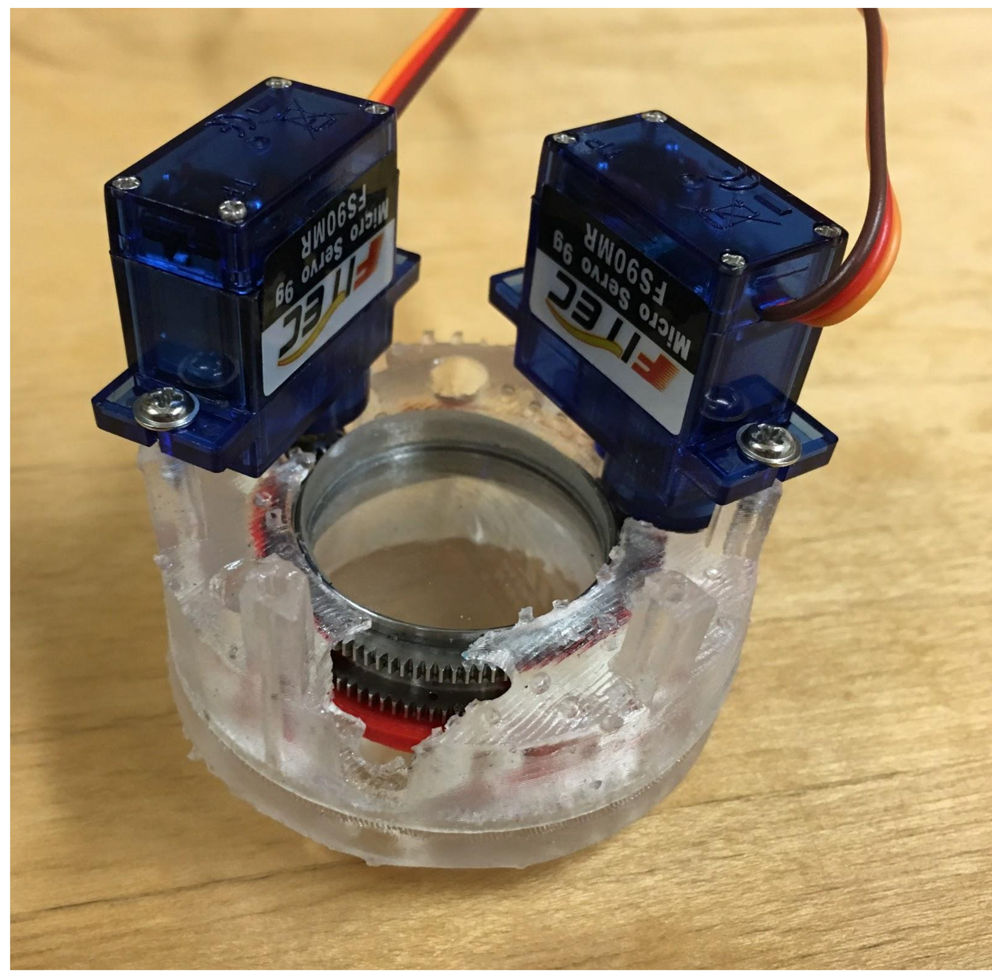

Figure 5. The printed Risley prism assembly. The outer casing (clear plastic) was printed using clear resin on a Formlabs Form 1+ printer. The lens holder (inner red ring) was printed using red PLA filament on an Ultimaker 3 printer. *Source: own work*

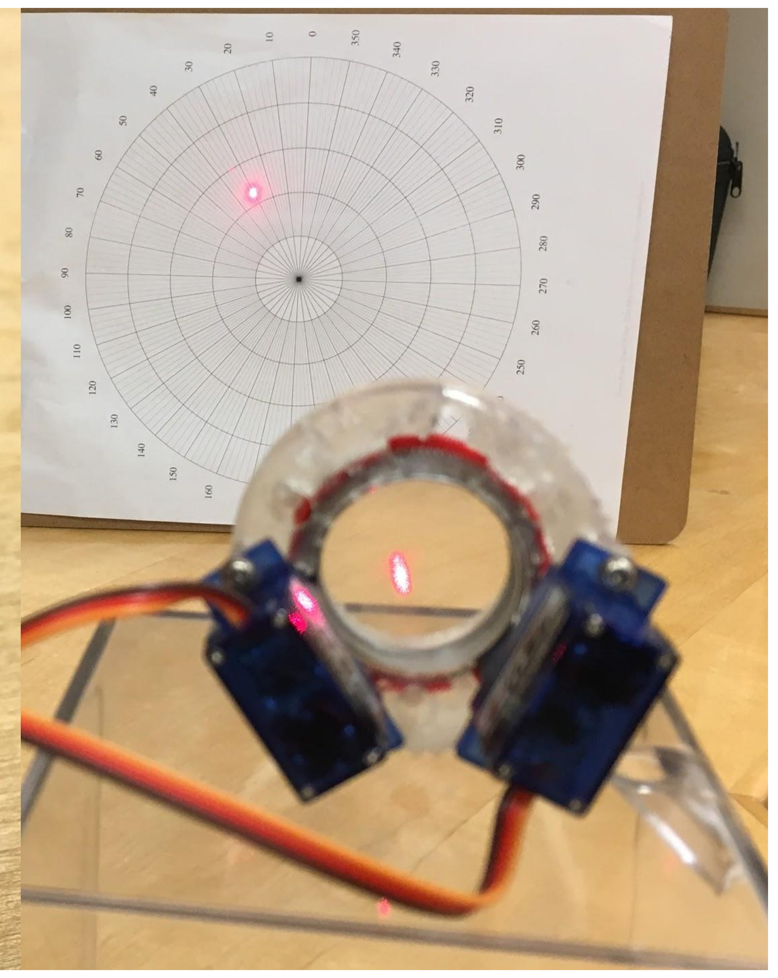

Figure 6. Steering a red laser beam using the device. The image of the laser is deflected from the center of the polar coordinate system although the beam passes through the center of the Risley prisms. *Source: own work*

Results

Commercially available Risley prisms (Thorlabs) were disassembled and paired with two continuous- rotation servo motors (Feetech). A housing for the prisms and servos was designed (**Fig. 4**) in SolidWorks (Dassault Systèmes) and printed (**Fig. 5**) using FDM and SLA 3D printers (Ultimaker; Formlabs). The servos were controlled through the GPIO interface of a Raspberry Pi 4 (Raspberry Pi Foundation) and laser beam steering was demonstrated (**Fig. 6**).

Future work

- Implement eye-tracking hardware and software on the Pi to automate servos
- Migrate low-level servo control to Arduino to improve accuracy
- Preliminary user studies to refine gaze tracking and detection of Maxwell's spot
- Switch to low-profile stepper motors to remove obstruction of peripheral vision by servos
- Miniaturize prism assembly and integrate into a wearable platform for strabismus trials
- Long-term clinical trials in strabismus patients to compare with current treatment options

References

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