

INSTRUMENTATION & TECHNIQUES

Artificial eye for assessing corneal-reflection eye trackers

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An artificial eye for assessing corneal-reflection eye trackers is described. The "eye" simulates an adult human eye and consists of a contact lens of the same curvature as the cornea.

To assess the performance of an eye tracker, it is necessary to present it with a precisely known input. For a corneal-reflection eye tracker with a bright-pupil (e.g., Hainline, 1981; Young & Sheena, 1975), this can be provided only by a device that simulates the optics of the human cornea and pupil. Such a device is shown in Figure 1. This "artificial eye" consists of a contact lens of the same curvature as the human cornea; the image of the illuminator that is reflected by this surface provides one of the two required images for the eye tracker. The second image, the bright-pupil, is provided by an aperture situated at the correct optical distance behind the "corneal" pole; this aperture is backed by white paper that serves as a diffuse reflector to simulate the fundus. The arrangement is rotated about a point, equivalent to the center of rotation of the human eye, by a fast high-torque galvanometer motor. The motor is specified in Figure 1; however, a pen motor from a good chart recorder would suffice. The shaft of the motor is also connected with a zero-backlash coupling to a linear potentiometer, which provides a precise and continuous readout of the angular position of the device. This is a simple and inexpensive arrangement and can be driven by a signal generator or a computer-generated signal. An outline of the artificial eye is shown in Figure 1a. All surfaces in the field of view of the eye tracker are painted flat black.

The optical geometry shown in Figure 1b is based on a simplified schematic eye of the adult human (see Bennett & Francis, 1962). The meniscus contact lens has zero power and the same curvature as the real cornea. (Unfortunately, a plano-convex lens, although cheaper, also produces a very bright reflected image from its second surface, and this image confuses the image-processing electronics of the eye tracker.) Since this lens has no dioptric power, it is necessary to position the sharp-edged "pupil" 3.05 mm behind the pole, rather than 3.6 mm,

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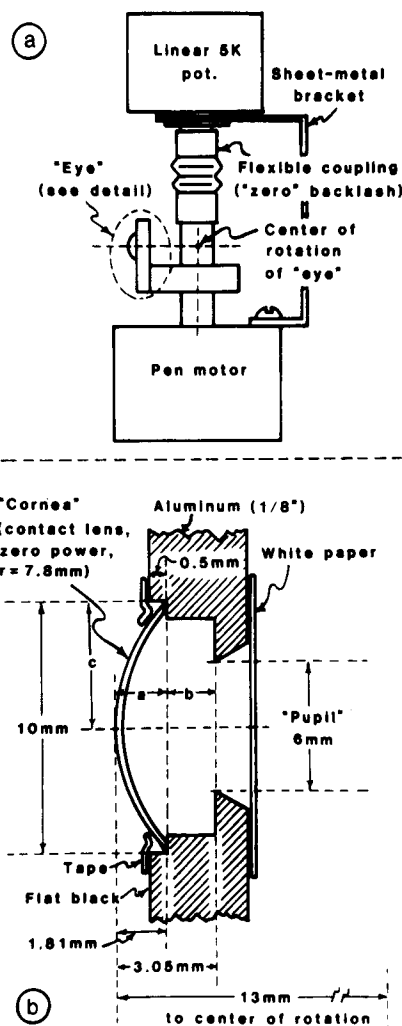


Figure 1. Outline of artificial eye for bright-pupil corneal-reflection eye tracker. Not to scale. Specific components used were: (1) corneal contact lens—zero power, 7.8-mm base curve, 0.2 mm thick, 10 mm in diameter, from Dow Corning Ophthalmics, Norfolk, VA; (2) pen motor—optical scanner G-330, from General Scanning, Watertown, MA; (3) flexible coupling—"nickel bellows" type, from Servometer, Cedar Grove, NJ.

as in the natural eye. Figure 1b also shows the details of the lens mounting. Care must be taken in placing the lens the correct distance $[(a+b)$ in Figure 1b] in front of the aperture, since this determines the eye tracker's gain. Assuming the lens is spherical, the depth of the contact lens (dimension labeled "a" in Figure 1b) is $r + \sqrt{(r^2 - c^2)}$, where r is the radius of curvature and c is the radial width of the lens. Calculation of the depth allows the correct indentation of the recesses to be made.

Although the artificial eye can rotate in only one dimension, it is small enough to be mounted on a camera tripod so that the tripod's panhead can be used to set the artificial eye's axis of rotation at any angle. Thus, the performance of the eye tracker in any direction can be assessed. The potentiometer not only provides the necessary readout for precisely adjusting the excursion of the "eye," but also mechanically damps overshoots from step inputs to the motor. By trial and error, we found a potentiometer that damped overshoot to less than 5% for a 10° movement while still maintaining a speed of $1,000^\circ/\text{sec}$ for a step input; this is adequate to simulate even fast human saccades.

This artificial eye simulates an adult human eye, but it can also be used to approximate an infant eye. The gain of the eye tracker is proportional to the distance between the center of curvature of the cornea and the plane of the entrance pupil (e.g., see Young & Sheena, 1975); cor-

neal asphericity has negligible effect. In the infant, the depth of the anterior chamber is about 70% of the typical adult's (Larsen, 1971). On the other hand, the radius of corneal curvature is only about 85% of the adult's (Mandell, 1967). These conditions cause the distance between the entrance pupil and the center of curvature to remain approximately constant from birth (see Bronson, 1982).

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