Autofocals: Automatically Adjusting Bifocal Glasses

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Introduction

This paper describes a prototype pair of glasses that change focus in response to the distance between the user and the object of focus. Initial responses are recorded in a heuristic fashion, and a survey provides usage behavior for users of current glasses solutions. It is hypothesized that the prototype will generally respond correctly to user behavior, and that the survey will indicate that automatically focusing glasses will resolve a minor but frequent annoyance for people who require distance and reading vision correction.

Background / Related Work

Attempts to integrate HCI with vision correction are currently limited. DeepOptics and Carlos Mastrangelo appear to have the closest related work in this field. All of these projects are still in a prototypical or exploratory phase.

Of somewhat related note was Google's attempt to bring data analysis into users' field of view with Google Glass. While this failed product may appear to dissuade the integration of HCI and glasses, the link between true glasses and Google Glass is only superficial. Glass did not attempt to automate vision correction for different focal lengths. Rather, it only added a layer of data (and distraction) between the user and the object of focus.

System Description

A pair of lens-less glasses frames was outfitted with a forward facing SR04 ultrasonic distance sensor over the bridge, and a mechanically adjusting lens system in front of one of the eyes.

The lens system consisted of a fixed convex lens (f = 18.7 cm) and a concave lens on a slider (f = -12 cm). The convex lens could move up to 12 cm away from the convex lens. Thus, the overall focal distance ranged from -33 cm when the lenses were together to 42 cm when the lenses were at their maximal separation. The convex lens moved on the slider via a rack and pinion, driven by a stepper motor controlled by an Arduino R3 microcontroller.

The SR04 ultrasonic distance sensor was also connected to the Arduino. The input signal was filtered in software with a median filter to ignore random spikes, and a low pass filter to ignore temporary swings.

Rather than try to continuously adjust the focus, the glasses simply chose whether to be at their maximal or minimal focal distance. The human eye naturally adjusts focus, so these lenses were only designed to correct for the inability to reach certain focuses., which is in effect what all glasses currently do. In addition, continuously adjusting the focus would be far harder to do accurately, and probably annoying for the user even if done accurately.

The threshold between near and far focus was given as ___ cm, with a hysteresis of ___ cm on either side to avoid the lenses from jittering back and forth at this threshold.

Evaluation / User Study

Evaluation of this system consisted of two parts: a heuristic observation of

how people used the current prototype, and a statistical analysis of a survey designed to gain insight into how people use currently existing glasses.

The heuristic study with the prototype was performed as follows. Volunteers would wear the glasses as best they could (often this required stabilizing them with one hand) and were told to look between a notebook, a laptop screen, and a whiteboard. It was observed (but unfortunately not recorded) how often the glasses would adjust correctly between near and far depending on what they were looking at. Heuristic conclusions are presented in the conclusion section of this paper.

The survey consisted of several questions, determining the participant's current vision correction solution, how often they performed certain tasks such as tilting their head to change focus with bifocals, and their overall satisfaction with their vision correction. Only one statistically significant correlation was found: bifocal wearers did not tend to wear distance glasses ($t(53) = 2.2$, $p < .05$, $r = -.48$).

Conclusion

From the heuristic observation of the prototype's usage, several improvements became readily apparent, as did an idea for an improved user study. First, there was much greater variation between how far some people read than assumed, implying that the near/far threshold should be user-configurable. Second, users did not necessarily center the document they were reading in their field of view. Sometimes the document would not be in front of the sensor. Although this may be due to users having to hold the prototype in one hand, future prototypes should have a wider angle of distance sensing. Third, any future prototypes must be lighter and better balanced to allow the user to wear them naturally.

To improve the user study, the lenses could be removed entirely. By attaching an LED and the distance sensor to the user's regular glasses or a lens-less frame, the accuracy of the near/far detection could be determined numerically without the added complications of the bulky prototype mechanism.

User studies concerning the mechanism itself could be run separately once a lighter, prescription-accurate system is devised. Improving the mechanism is a separate challenge, most promisingly addressed by Mastrangelo and DeepOptics through liquid crystal systems, but also by Shian, Diebold, and Clarke in 2013 through the use of electroactive polymers.

As for the survey, the only statistically significant correlation was that bifocal wearers did not tend to wear distance glasses. This might imply that bifocals do a better job replacing distance glasses than reading glasses, but more testing is required before that conclusion can be drawn. Intuitively this makes sense to this author, as bifocals have the "regular" portion of their lenses devoted to distance, and users must look down in order to focus on reading. If an automatically focusing system can improve upon the reading experience of bifocal users without compromising the distance viewing experience, that might be their biggest advantage over currently existing solutions.

Overall, the greatest success in this prototype was in the sensing, filtration, and hysteresis of the distance, while most still needs to be put into the mechanical components of the device.