High-order Power Map and Low-order Lensmeter using a Smartphone Add-on

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Abstract: We developed a portable, low-cost, accurate, wavefront sensing lensmeter for optometry applications: the Netrometer. The average absolute errors for sphere (SPH), cylinder (CYL) and axis of astigmatism (AXIS) on single vision glasses were, respectively: 0.058 ±0.118 diopters (m^{-1}), 0.076 ±0.152 diopters (m^{-1}) and 3.4 ±3.6 degrees (N=320). In addition to low-order measurements, the Netrometer produces in real-time a power map of the perceived refractive values. The design uses no moving parts and no additional refractive elements to the cellphone's camera.

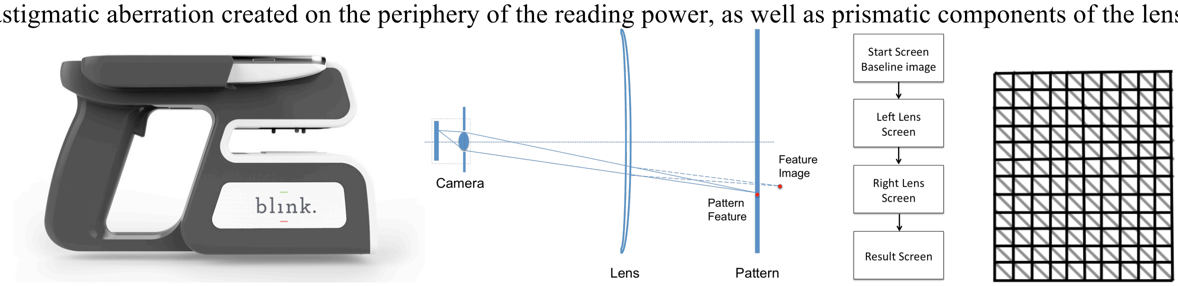
OCIS codes: (170.4460) Ophthalmic optics and devices; (330.7327) Visual optics, ophthalmic instrumentation

1. Introduction

Optometrists and ophthalmologists use lensmeters to assess the current optical correction used by the patient. It is considered a fundamental piece in generating the new refractive prescription. Commercial lensmeters are stand-top, bulky, and sensitive devices that operate plugged in or with a hefty battery and require significant training to acquire accurate readings. The proposed Netrometer (see Figure 1a) is a portable add-on for smartphones that consists of hardware with a clamp mechanism to hold the lens in place while imaging a known pattern through the lens. It is lightweight and portable, with the cost of parts under $10. The Netrometer computes SPH, CYL and AXIS for the given lens. In addition, it computes a 2D map of optical powers of the lens, allowing the assessment of progressive lenses. This device when used along with the Netra refractor [1] has the potential to significantly change the practice of optometry worldwide, increasing access to eyeglasses for the 2.4B people in need today.

2. Materials and Methods

The lens refraction meter device is divided into two functional parts: the hardware and the software. The hardware consists of a gun-like housing that holds the smartphone up top. It was designed to encompass the probing sensor and a clamp/trigger mechanism that secures the lens flat to the desired plane. The glasses are introduced in an insertion gap such that the lens is in the field of view of the smartphone camera. An acrylic light-pipe transmits the flash from the smartphone to the pattern, around the lens to avoid reflections and unwanted distortions. The small aperture of the smartphone camera acts as a pinhole, measuring the optical refraction along the same path as the gazing visual axis when the lens is in front of the eye (see Figure 1b). The calibration for image change ratio to refractive power in diopters is taken from a calibrated curve, as shown on Figure 2a. The system is currently designed for the Samsung Galaxy S4. The first screen takes a picture of the pattern without the lens (see Figure 1c for app flow; 1d for pattern). Then images of the pattern are taken for the left and the right lenses. The software computes the difference between the patterns and best-fits the results. The result screen shows the optical powers in terms of low-order aberrations (SPH, CYL, AXIS). In the advanced mode, the Netrometer displays the 2D profile map of the lenses, including single, bi-focal and multi-focal lenses (similarly to [3-5]). The user can navigate the map to identify features of the progressive lens manufacturing such as the distance and near fields of view, corridor length and angle between distance and reading powers, the consistency of the intermediate powers, the strength of the astigmatic aberration created on the periphery of the reading power, as well as prismatic components of the lens.

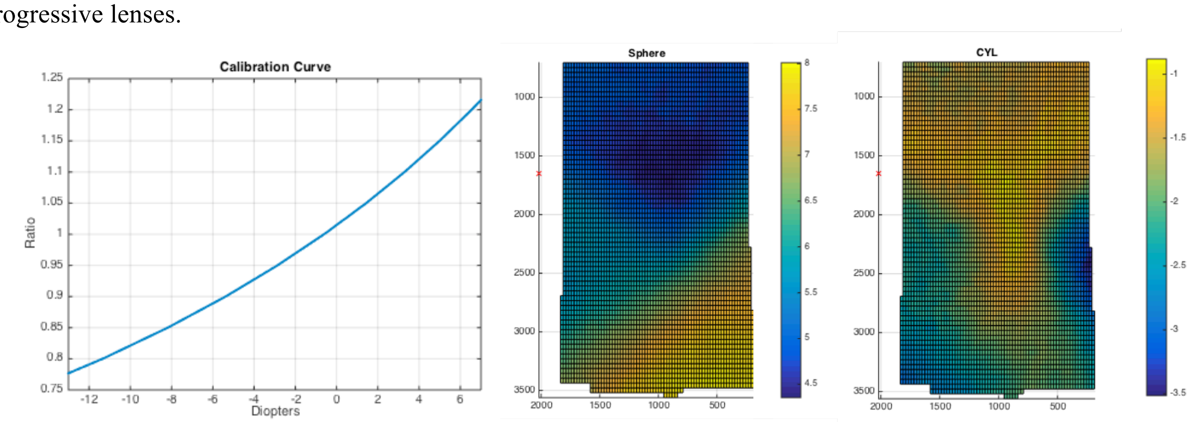


(a) (b) (c) (d)

Figure 1. (a) Netrometer device, (b) Schematics of refractive power probing, (c) Screen flow of Netrometer app, and (d) Pattern image.

3. Results

To evaluate accuracy, we have tested 10 pairs of single vision glasses with known powers by 16 users (N=320). The average absolute errors and standard deviations for SPH, CYL and AXIS were, respectively, 0.058 ±0.118 diopters (m^{-1}), 0.076 ±0.152 diopters (m^{-1}), and 3.4 ±3.6 degrees. The difference in vector power domain is 0.58. The total processing time per lens was less than 1.5 seconds. The measurements between different users were not statistically different. Additionally, we assessed 10 progressive lenses from different manufacturers. The Netrometer app displays both the SPH and CYL power maps for an area of the lens imaged, Figure 2b. The wavefront difference was however hard to identify due to the nature of the Netrometer design: perceived power accounting for gazing instead of the power of the light path parallel to the normal vector of the back surface of the lens that is measured by all other wavefront sensing lensmeters. The perceived power is however, the ultimate unit to assess the quality of progressive lenses.



(a) (b)

Figure 2. (a) Calibration curve, (b) high-order power map of a progressive lens: SPH and CYL maps for the same lens.

4. Conclusions

The proposed system measures single vision lenses and maps progressive lens power profile. The single vision feature has accuracy levels comparable to current commercial lens meters. In addition to that, the Netrometer produces the real-time 2D profile map with local refractive values. We have concluded that our technique outputs a fair estimation of the perceived optical power in true usage conditions. Currently, no other device presents similar capabilities, along with being portable and low-cost. This work was partially supported by NSF SBIR 1345968.

5. References

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