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COMPUTER VISION CATARACT SCREENING EQUIPMENT: TECHNICAL SPECIFICATIONS

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ABSTRACT

Difficulties in obtaining a diagnosis and treatment and financial and logistical problems are identified as the leading causes of the high prevalence of blindness due to cataracts worldwide. With the increasing availability of portable fundus cameras and slit-lamp adapters for smartphones, cataract diagnosis can be enhanced in remote regions at a low cost using easy-to-handle devices. The aim of this article is to describe a patent application for a device created to capture lens images and classify cataracts automatically based on computer vision methods. The results are displayed after rapid calculations using numerous cataract measurement-based parameters, such as average color, standard color deviation, and comparison of color histograms. Future clinical validation studies will be performed based on this description.

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INTRODUCTION

Difficulties in accessing diagnosis and treatment as well as financial and logistical problems to screening surgical cases are the main causes of the high prevalence of blindness due to cataracts worldwide. (1) (2) Innovations in cataract diagnosis methods improve and increase the coverage and reduce costs of the therapeutic process.

With age, nuclear fibers become more compact and consequently opaque. Thus, the lens nucleus becomes less transparent and causes poor vision and optical aberrations. Clinically, the nucleus changes color from translucent to yellow to orange and eventually brown(3). Most cataract screening methods are focused on functional findings, as is the case of low visual acuity and low contrast vision. The indication for surgery depends on specific exams performed by ophthalmologists(4). The gold standard for slit-lamp grading of cataracts is the Lens Opacities Classification System III (LOCS III) developed in 1993. (5–7) The classification system employs 6 slit-lamp photographs for nuclear color grading (NC) and nuclear opacity (NO), and other systems are used for the classification of nonnuclear cataracts (8). However, there is a consensus that interobserver biases occur when using this classification. Several automated platforms for diagnosing cataracts have already been created, such as the systems developed by ANSARI et al. (1999)(9) and LIM et al. (2014)(10). However, these platforms do not combine the characteristics that determine its dissemination in public health policies aimed at this problem. Given that cataracts primarily involves a condition that results in a change in lens color, the purpose of this article is to introduce a new device that is inexpensive and easy to handle and transport to track cataracts with surgical indications through photographic records under controlled lighting and focus conditions.

METHODS

Equipment Description: The Portable Device presented in this research is the "Photo sensor for detecting cataracts with surgical indication" with a patent application from the National Institute of Industrial Property (INPI) under number BR 10 2017 023842 3. The device consists of equipment that allows photography under controlled lighting conditions and lens focus, provides automatic markings of the pupillary region, measures parameters related to the region's color and automatically analyzes these parameters. (Figure 1). The equipment includes the following components:

(1) WN STD Series Neutral White LED Lighting System with 1 Watt power (11). One hundred lumens output at 120 degrees of dispersion. Color temperature 3800-5.000 Kelvin. The lighting system is positioned at 45 degrees to the detection system. In addition to 4 TSAL6200 infrared LEDs(12) with a wavelength of 940 nm, 160 milliwatts of power is delivered in 20 degrees of dispersion, emitting 72-200 mW/sr.

(2) The detection system consists of a camera with a Sony IMX219 sensor(13) and 8 megapixels. The camera lacks an infrared filter but has a Macro Lens with 20 diopters and a focal length of 5 centimeters.

(3) The processing system consists of a Raspberry pi 3 model B+(14) minicomputer with 32 gigabytes of solid disk memory, 1 gigabyte of RAM, and a Cortex-A53 (ARMv8) 64-bit SoC @ 1.4 GHz processor embedded with a Raspberry Pi OS system (32-bit)/2021-01-11.

(4) Other peripheral components include batteries, infrared sensors, protective covers, and change signaling systems with multicolor LED 'RGB' (red, green, and blue).

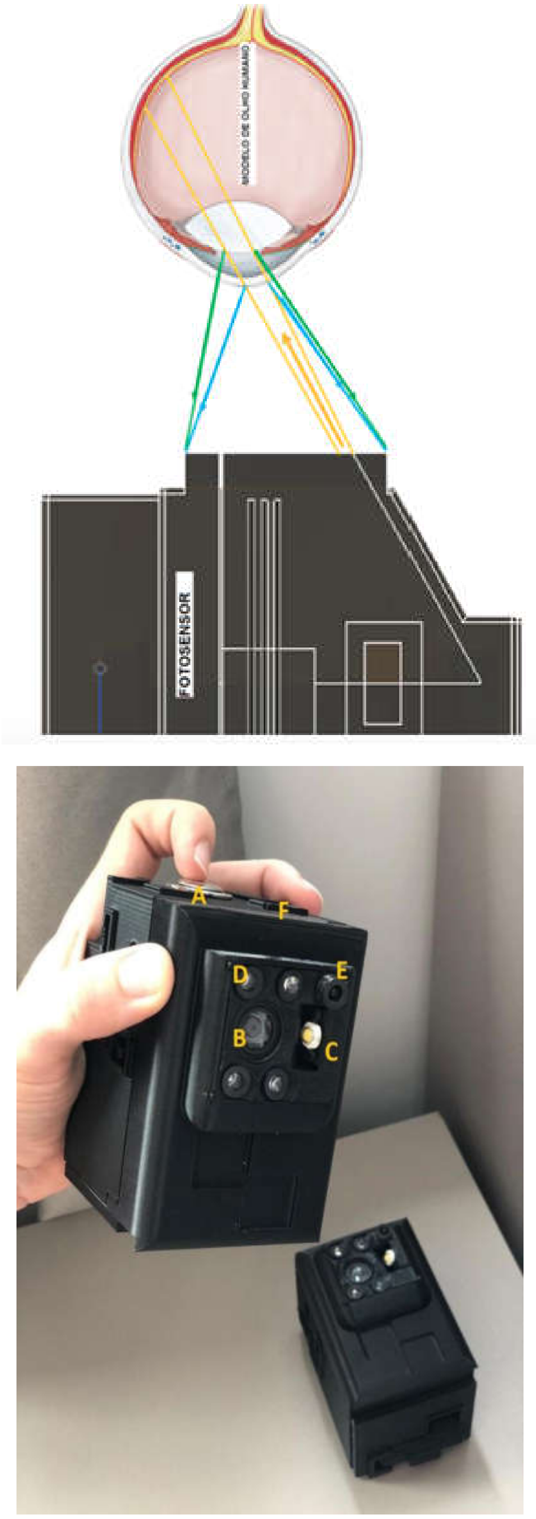


Figure 1. Operating diagram of the portable device (left) and photograph showing the grip (right)

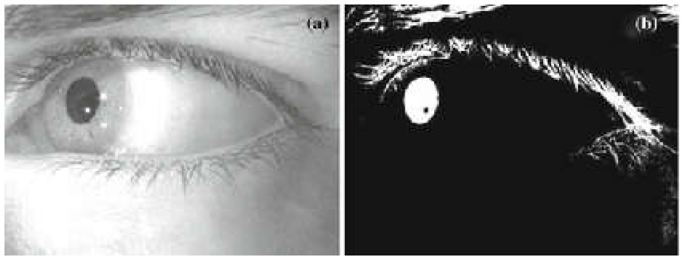
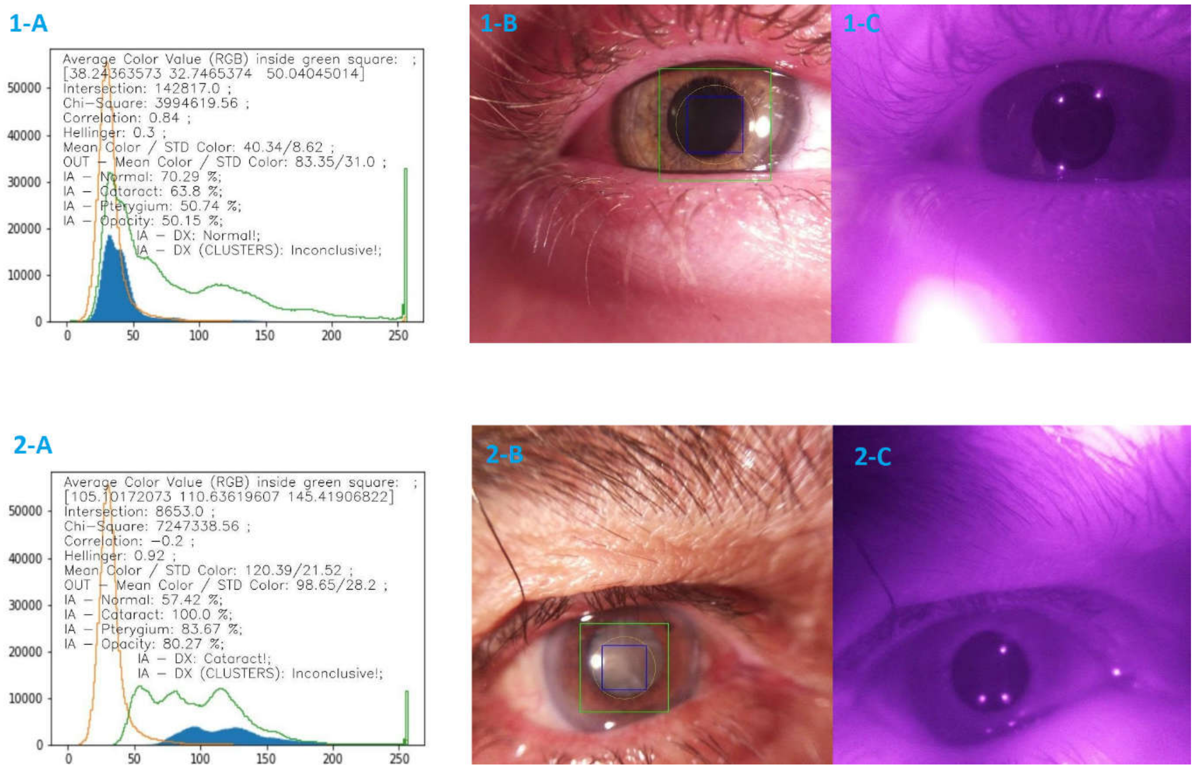


Figure 2. Threshold example (right) applied over infrared photograph of the human eye in grayscale (left) (25)

Use of the equipment: The camera must be positioned in front of the eye to be examined (I) at a distance of approximately 5 centimeters (II) in a low-light environment (III). If any one of the three requirements is not fulfilled, the equipment signals through the sequential blue blinking of the RGB LED. Once these requirements are met, the equipment's Top Button is clicked. The system sequentially captures an image with infrared LEDs lit only and another image with a White LED lit only. After a few seconds, after the analysis is performed by the minicomputer. The equipment provides a signal of the results using the RGB LED as follows: red color indicates cataracts, green indicates the absence of cataracts, and blue color indicates that the system is not able to perform the analysis. Once the result is delivered, the system is able to perform another measurement. The photographic records and measurements are automatically sent by e-mail when there is an internet connection via Wi-Fi.

Method of analysis of the image obtained: The captured images are analyzed using software developed using Python language, computer vision and deep learning libraries called OpenCV® (IBM) and TensorFlow® (Google), both of which use open source code. Initially, through infrared image processing, the pupillary region is located based the following method:

1. The image is converted to grayscale;
2. In a cycle, a process called Threshold (Figure 3) is repeatedly performed over the image, where the pixels above a certain threshold appear entirely black, and the pixels below the threshold appear white to highlight the pupillary region, where more significant absorption of infrared radiation occurs. Once this transformation occurs, the image is blurred to smooth all the edges;
3. Using the image above, a search is performed to identify for pixels that maintain some geographic and color relationship with each other, find the image components, among which is the pupillary region that is selected, and filter it from the others based on its area characteristics (considered values between 50 thousand and 10 thousand pixels), circularity (considered a minimum value of 0.1), convexity (considered a minimum value of 0.1) and inertia (considered a minimum value of 0.5). Once an object with the aforementioned characteristics is identified, the cycle of iterations on the infrared image stops, and the pupillary region is marked;
4. The marking over the pupillary region identified in infrared photography is transposed to sequential photography with white light. These steps are performed one millisecond apart. After this photograph is obtained, a third posterior infrared photograph with white light serves as a control to determine whether significant movement of the patient occurred between the photographs, in which case the device disregards the measurement and signals and indicates that it was not possible to make a diagnosis;
5. When pupil location requirements are met, several measurements are taken over this area using white light photography, including average color (for red, green, and blue components, plus an overall average) ranging from 0 to 255 by convention. Additionally, the standard deviation of the overall average color and the linear correlation between the color histograms of the photograph compared to a standard



CAPTION:(1-A) Measurements obtained in a patient without cataracts; (1-B) Markings in the pupil region in white LED photography in a patient without cataracts; (1-C) Infrared photograph of a patient without cataracts. (2-A) Measurements obtained in a patient with cataracts; (2-B) Markings in the pupil region in white LED photography in a patient with cataracts; (2-C) Infrared photograph of a patient with cataracts.

Figure 3. Photographic record demonstrating the parameters measured by the equipment and the markings in white light and infrared photography

support the training of physicians(15). The challenge is to reduce the costs of the equipment that will capture the data and simplify its use without reducing accuracy. In addition, a perennial platform should be used that is not impacted by the constant change in components and equipment specifications, thus avoiding deterioration in the accuracy of technologies involving computer vision. In this article, a low-cost device that is easy to handle and transport that obtains photographic records for surgical cataract tracking was presented. Teleophthalmology services currently work with data storage and forwarding systems (RATHI) rather than overload specialists when receiving exams in a block. In this sense, concerning the remote diagnosis of cataracts, several initiatives seek to automate this process or support the clinical decision to accelerate it(16). In China, several technologies using deep learning were conceived based on an extensive database of slit-lamp photographs or even through photographs on smartphones collected from the service health network to provide a national cataract screening program. In this context, Wu et al. (2019)(17) trained a convolutional neural network based on an architecture called ResNet (with good performance in various segments of science for image classification). After training with 37,638 images, the area under the ROC curve was more significant than 91% for the diagnosis of cataracts in need of reference. Moreover, a preliminary study with 40,000 eye images and 1,000 referable cataracts detected was conducted in 65 Chinese community hospitals(18).

Zhang et al. (2019)(19) used fundus imaging to classify cataracts using the same technique as ResNet and transfer learning. An average accuracy of 92.66% was achieved in the classification of cataracts into six distinct groups. However, there was a limitation on accuracy for measurements on poor-quality images. Ting et al. (2019)(16) highlight the importance of these autonomous technologies in the home screening of patients with cataracts. This method can be performed by family members, and the information can be used to refer individuals for specialized services. All these technologies are relevant because 70.5 million cases of blindness were projected to occur by 2020 due to cataracts globally (20).

In 2021(21), Ting et al. assessed 13 other studies on computer vision and cataracts in a literature review. None of these studies validated the technologies prospectively versus clinical outcomes. In addition, they highlight that more efforts have been applied in posterior segment pathologies. Other types of equipment with a similar proposal have already been created, such as the patent application registered under the number WO2011091804A1(22), which proposes to analyze cataracts through the amount of light reflected by the lens as a single parameter. In addition, patent number US9456926B2(23), which uses intraoperative cataract optical coherence tomography, and a cataract grading system through the Pentacam System, patent number CA2596560A1(24), have also been developed. The equipment reported in this article is distinguished because it uses a camera without an infrared filter for measurements. Several parameters in addition to the amount of reflected light are measured. One goal of the device was to optimize its portability in addition to the simplicity by which its results are displayed. Therefore, the proposed device can be used even by those with a minimum level of education in remote regions as a screening method before specialized ophthalmological evaluation. However, further validation studies in specific subgroups are needed. To validate the device, photos will be compared to the medical examination results based on a slit-lamp using LOCS III classification.

Potential Pitfalls and Troubleshooting: The equipment may present difficulties in characterizing posterior subcapsular cataracts due to the inclination of its illumination.

Cataracta Rubra and *Cataracta Nigra* may also be misdiagnosed due to their degree of absorption of white light.

The equipment may incorrectly diagnose pseudophakic posterior capsule opacities.

These biases are resolved by the equipment automatically sending the collected images to a medical reviewer. Moreover, machine learning solutions will be available as the database grows.

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