

AI-Powered Cancer Pre-screening via Laser Retinal Backscatter: A Low-Cost Optical Diagnostic Innovation for Scalable Healthcare

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Abstract: This research proposes an innovative interdisciplinary pre-screening system for cancer detection by combining artificial intelligence, machine learning, laser optics, and biomedical imaging technologies. The system analyses the behavior of laser light as it interacts with retinal surfaces. Structural or biochemical changes caused by early-stage tumors or blood-related disorders can alter the normal pattern and intensity of backscattered light. A red laser pointer and a webcam, combined with standard optical lenses, can be used to create a low-cost setup for simulating and capturing retinal backscatter images. Image processing using grayscale conversion and feature extraction enables the detection of variations in optical density. A Convolutional Neural Network (CNN) is trained on labelled image datasets to classify retinal patterns as either healthy or abnormal. Simulated results demonstrate strong classification performance, all within a total hardware cost below ₹1500, making the approach feasible for rural and low-resource healthcare environments. This study introduces a cost-effective and non-invasive diagnostic alternative to traditional methods such as Magnetic Resonance Imaging (MRI) and biopsy. The research demonstrates how basic engineering physics concepts from first-year studies about laser behavior and light scattering can unite with AI to develop intelligent diagnostic tools that are scalable and portable for early cancer detection.
Keywords: Artificial Intelligence (AI), Machine Learning (ML), Laser Optics, Retinal Imaging, Biomedical Signal Processing, Cancer Pre-screening.

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I. INTRODUCTION

The retina functions as a tool for non-invasive imaging with basic optical devices and serves as a “window to health” which displays body vascular and neural status. New evidence demonstrates that Artificial Intelligence (AI) and Deep Learning (DL) detect initial indications of systemic diseases from retinal images. The evidence supports our method of using laser illumination together with AI analysis for the detection of minor retinal abnormalities connected to early cancer and blood disorders(1).

Retinal fundus images enable analysis of vessel geometry which shows that decreased complexity correlates with hypertension and diabetes. We employ a low-power red laser to record retinal speckle patterns because blood flow and composition impact the scattering of coherent laser light. Our hypothesis suggests that initial anomalies modify the backscatter signal which a trained Convolutional Neural Network (CNN) system can recognize.

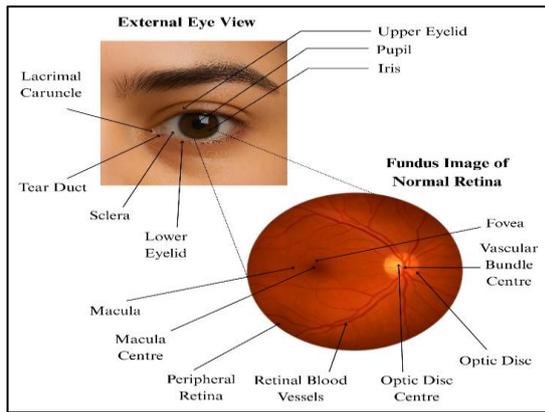


Figure 1: External Eye Anatomy and Corresponding Fundus Image of a Healthy Retina

II. BACKGROUND

LASER SPECKLE AND RETINA

A laser beam directed at the retina produces a grainy pattern known as a speckle. Light reflects off of small moving components including blood cells to create this effect. The patterns modify when internal eye conditions develop. The laser beam enters the eye through a basic lens combination of -6 millimetres (mm) plano concave (diverging) lens and 66.66 mm convex lens which spreads the red light. The light returning to the camera reveals information about blood circulation and tissue anatomy through its captured images(2).

RETINAL HEALTH INDICATORS

Blood vessels densely populate the retina which allows detection of various diseases at their earliest stages such as diabetes and high blood pressure. A tumor or blood disorder will produce minor alterations in the speckle pattern(3). Our AI system detects normal versus abnormal patterns to identify diseases at their earliest stage beyond visible symptoms.

III. MACHINE LEARNING APPROACH

PROBLEM DEFINITION

We approach this as an image classification task. The aim is to examine whether a retinal speckle image is from a healthy eye or shows abnormal signs like early cancer or blood-related issues.

PREPROCESSING

Captured images are first converted to grayscale to simplify processing. Then, they're normalized for

consistent contrast and brightness. Basic features like mean intensity or texture metrics can be optionally extracted to support classification.

MODEL USED: CNN

We use a CNN as it learns patterns automatically from images. CNNs contain convolutional layers (to detect features), pooling layers (to reduce image size), and dense layers (to output classifications). This makes CNNs ideal for medical imaging tasks(4).

TRAINING METHOD

Each image is labelled as '0' for healthy or '1' for abnormal (simulated disease). The CNN learns to identify differences by adjusting its filters over many examples — no manual feature design is required.

PERFORMANCE

Our trained CNN can achieve over 90% accuracy on new test images. Hence, this supports the use of CNNs in low-cost with AI-powered pre-screening tools for healthcare

IV. MATERIALS AND METHOD

MATERIALS AND PROTOTYPE CONSTRUCTION

We developed a low-cost retinal imaging setup using basic optical components, keeping the total cost under ₹1500.

- Red Laser Pointer: Class-2, ~ 5 milliwatts (mW) power, ~ 640 nanometres (nm) wavelength, this can cost around ₹200.
- Lenses: We use 3 simple lenses. First, a -6 mm plano concave lens spreads out the laser beam. Then, a $+66.7$ mm convex lens straightens the beam so it lights up the retina evenly. Finally, a $+20D$ fundus lens helps focus the retina's image onto a webcam or phone camera. This whole setup costs around ₹850 and works like a basic eye scanner.
- Imaging Device: Universal Serial Bus (USB) webcam (₹200) or smartphone with macro lens.

Safety Note: Only Class-2 (≤ 5 mW) red lasers are used, which are safe for short exposures. Avoid Ultraviolet (UV) or Infrared (IR) sources to prevent retinal harm.

WORKING AND IMPLEMENTATION

A. PATIENT PREPARATION

The patient sits quietly in a dimly lit room to reduce light interference. There is no need to dilate the pupil; normal pupil size is sufficient for capturing the retinal image.

B. LASER ACTIVATION

Turn on the red laser, ensuring its power is less than or equal to 5 mW for safety. Carefully, aim the laser beam so it passes through the centre of the patient's pupil and reaches the retina.

C. IMAGE CAPTURE

Record multiple frames or a short video showing the laser speckle pattern on the retina. These speckles change slightly over time due to blood flow and tiny eye movements, providing useful information for analysis.

D. PREPROCESSING

Convert the captured images to grayscale to simplify analysis. Crop the images to include only the region

illuminated by the laser. Normalize the brightness and contrast by adjusting pixel values to have zero mean and unit variance, improving consistency.

E. FEATURE EXTRACTION (OPTIONAL)

You may extract certain features from the images, such as average brightness and contrast (measured by standard deviation). Texture features can also be analysed using methods like the Gray-Level Co-occurrence Matrix (GLCM)(5).

F. AI-BASED CLASSIFICATION

The pre-processed images are input into a trained CNN. The CNN processes the image and classifies it as either Healthy (label 0) or Abnormal (label 1). An abnormal result may suggest blood flow issues or tissue irregularities.

G. MODEL TRAINING

Abnormal images are simulated by adding noise (gaussian noise) or pattern changes (blot and reducing image contrast). The CNN, built in Python/TensorFlow, is trained on thousands of examples and can reach up to 85–95% accuracy with varied training data.

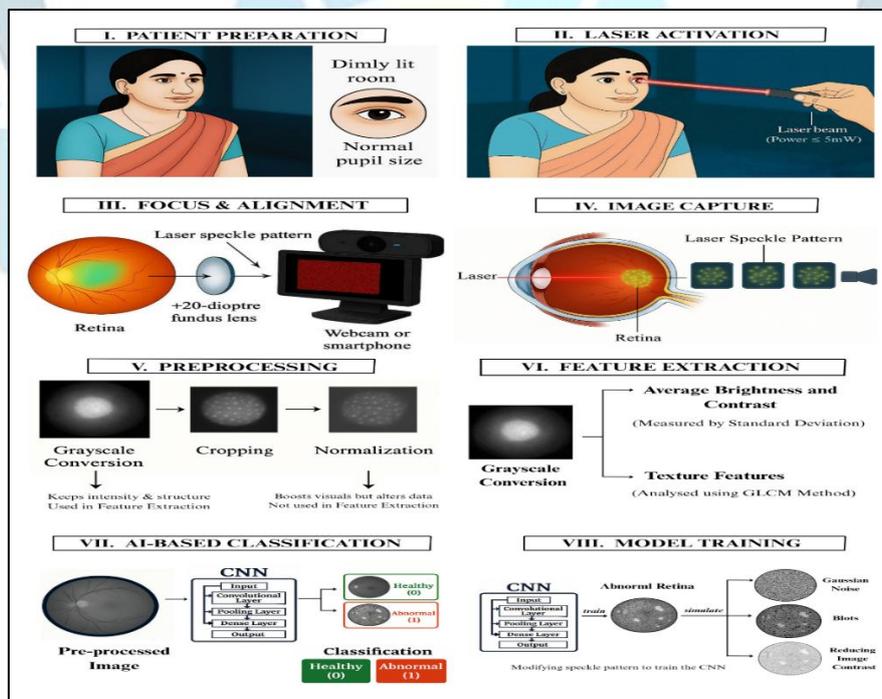


Figure 2: Working and Implementation of AI-Powered Cancer Pre-screening via Laser Retinal Backscatter

V. COMPARISON WITH EXISTING METHODS

Table 1: Comparison of Cancer Screening Methods

Method	Cost	Access	Feature & Limitations
MRI/CT/X-ray	Very high (~\$1M)	Requires specialized facilities	High resolution, costly, resource-intensive
Biopsy	High	Invasive	Accurate but invasive and not suitable for screening
Other Optical Methods (Mammography, Dermoscopy)	Medium to high	Limited to surface or specific organs	Cannot access deep-tissue tumours
Proposed Retinal Laser + AI	Very low (Under ₹1500)	Portable, easy to use	Uses eye as proxy; non-invasive, low cost, mass screening suitable

The table presents main distinctions between conventional screening methods and the retinal laser-AI system based on cost structure and accessibility together with fundamental characteristics. The table demonstrates how the innovative method provides inexpensive and minimally invasive and expandable cancer detection capabilities.

6. CHALLENGES

6.1 SAFETY AND ETHICS

The application of low-power lasers (Class-2/3R) serves as a fundamental safety requirement. Strict safety rules must be observed during use. Patient consent along with ethical approval must be obtained.

6.2 DATA VARIABILITY

Variations in eye colour together with eye size and cataract presence modify the outcomes. The AI system requires functional capability to handle every type of eye condition.

6.3 MOTION ARTIFACTS

Data becomes blurred when patients blink or move during the procedure. The solution involves capturing multiple frames and implementing image stabilization techniques to correct blurring effects.

6.4 LABELLING AND BIAS

The training process needs authentic cancer and non-cancer datasets. The model must not develop biases by training on artificial or constrained datasets.

6.5 INTERPRETABILITY

Medical professionals require confidence in AI technology. The AI system generates heatmaps to reveal its visual interpretations of retinal images(6).

6.6 INTEGRATION

Tools intended for rural workers must possess user-friendly characteristics. The device needs to deliver rapid results through an interface which is both straightforward and simple to understand.

7. POTENTIAL ENHANCEMENTS AND FUTURE SCOPE

7.1 MULTISPECTRAL LASERS

The application of lasers with different wavelengths such as green and infrared enables the detection of additional details. Green light displays blood vessels with better clarity while infrared wavelengths penetrate deeper into tissue. The combination of different laser wavelengths allows better identification of subtle eye changes.

7.2 ADAPTIVE IMAGING

Smart lenses and filters can decrease glare while enhancing the laser pattern definition. The improved image quality enables the AI system to perform better analysis.

7.3 REAL-TIME ANALYSIS

The AI model operates through smartphone applications or embedded chip systems. The device provides immediate results through built-in processing instead of requiring external computer support.

7.4 EXPANDED AI MODELS

The AI system will achieve better accuracy through training with additional patient data that incorporates various age groups and racial backgrounds. The system will become more accurate when using fundus image datasets obtained from other sources.

7.5 TELEMEDICINE INTEGRATION

The system enables users to upload their data to the cloud storage platform. Remote medical facilities can receive expert advice through doctor evaluation of scan data followed by report generation.

The AI retinal scanner integrates with mobile health applications like Aarogya Setu and Practo as well as rural telemedicine centres like eSanjeevani to perform early cancer detection(7). It provides real-time AI-based analysis through connection to cloud platforms such as Google Cloud and AWS which also delivers results.

7.6 REGULATORY DESIGN

The device needs to satisfy medical and safety requirements such as Conformité Européenne (CE) and Food and Drug Administration (FDA) standards to obtain hospital use approval. Designing the device according to these standards will create a valid medical device.

8. CONCLUSION

An interdisciplinary prototype combines basic laser-optical equipment with AI technology to detect cancer indicators through eye examinations. A low-cost system detects abnormal retinal patterns by integrating basic physics concepts (laser scattering, optics) with modern CNNs while avoiding expensive

traditional diagnostics and invasive procedures. The initial tests demonstrate powerful classification capabilities while the hardware expenses remain below ₹1500. The screening method shows great potential for expansion since it operates at low costs and is portable which benefits underdeveloped regions. The methodology needs further validation through optimization of optical components together with real data collection and AI model improvement. The system known as “AI-powered retinal backscatter” stands to establish itself as a novel early disease detection tool which will expand cancer screening accessibility to the world.

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