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Deep Learning-Based Glaucoma Detection Using Cropped Optic Disc Regions

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Abstract:

Glaucoma, a progressive and irreversible optic neuropathy, results from increased intraocular pressure (IOP) due to impaired aqueous humor drainage between the iris and cornea. This condition leads to optic nerve head damage and visual field loss, often progressing to complete blindness if undetected. Referred to as the "silent thief of vision," glaucoma typically lacks early symptoms, making timely diagnosis critical. However, conventional detection methods are resource-intensive, require expert ophthalmologists, and involve high-cost equipment, limiting their scalability and accessibility.To overcome these challenges, this study presents an automated glaucoma diagnosis framework using deep learning techniques focused on region-specific analysis of retinal fundus images. A novel private dataset comprising 634 color fundus images—annotated by a pediatric ophthalmologist and a glaucoma specialist from Bangladesh Eye Hospital—served as the foundation for model training and evaluation. Deep learning models such as EfficientNet-B3, MobileNet, DenseNet, and GoogLeNet were employed on cropped optic disc and cup regions. EfficientNet-B3 outperformed other models, achieving a test accuracy of 96.52%, an F1-score of 95.12%, and a ROC AUC of 95.74%.Further, we developed a custom dataset by segmenting retinal blood vessels using a U-Net model trained on the High-Resolution Fundus Image Database. MobileNetV3 applied to this dataset demonstrated encouraging results, with a test accuracy of 83.48% and an F1-score of 79.57%.The outcomes of this research emphasize the potential of deep learning in facilitating early, efficient, and cost-effective glaucoma screening. Incorporating vessel segmentation and optic region cropping enhances model focus and diagnostic accuracy, promoting scalable solutions for widespread clinical deployment and improved accessibility in resource-constrained environments.

Keywords: EfficientNet, MobileNet, Glaucoma Detection, Fundus Imaging, Deep Learning, Image Classification, U-Net, Image Segmentation

1. INTRODUCTION:

Glaucoma is a well-known cause of permanent blindness across the world. Glaucoma is an optic neuropathy that causes persistent vision loss due to damage to the retinal ganglion cells [1]. This eye illness is caused by structural alterations in the retina, particularly in the optic nerve head (ONH) area [2]. Open-angle glaucoma (OAG) is perhaps the most common kind of glaucoma. It begins with progressive congestion of the drainage system (angle between the iris and the cornea), which leads to expansion of the optic cup area and increased ocular pressure [3]. Angle-closure glaucoma (ACG) is another kind of glaucoma caused by closed drainage canals and a sudden, fast rise in intraocular pressure [4]. According to the World Health Organization (WHO), glaucoma is the second leading cause of visual loss and blindness worldwide. It may afflict anybody at any age, although it is more frequent among the elderly. Glaucoma is one of the primary causes of blindness in persons over the age of 60. Glaucoma affects almost three million Americans, with 2.7 million of those aged 40 and over [5]. Certain types of glaucoma have no warning indications. The impact is so progressive that patients cannot identify a loss in vision until the sickness is at an advanced stage, and why it is termed the stealth thief of sight. Glaucoma affects about 80 million individuals globally in 2020, and this number is expected to rise to more than 111 million by 2040 [5].

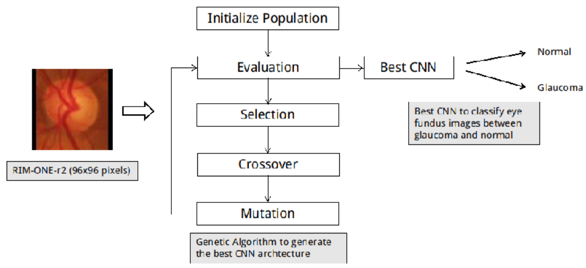

Fig.1.1: Example figure

Although there is no treatment for glaucoma, early detection may avoid major visual loss [6]. Because of the varied eye characteristics of each person, there are numerous approaches for detecting and identifying glaucoma [7]. Traditional glaucoma detection procedures are based on the validation of six basic factors: Tonometry, Ophthalmoscopy, Visual Field Testing, Gonioscopy, Nerve Fiber Analysis, and Pachymetry, which are briefly explained in the following paragraphs. Tonometry: Tonometry, often known as intraocular pressure (IOP), is a standard technique for assessing intraocular pressure [2]. Ocular pressure typically varies between 12 and 22 mmHg. People with higher-than-average ocular pressure are more prone to develop glaucoma. However, having greater than usual pressure does not automatically imply glaucoma. Glaucoma, on the other hand, may occur in those with low eye pressure rather than high pressures. Ophthalmoscopy: This procedure assists in the detection of glaucoma damage by evaluating the shape and colour of the optic nerve [8]. More tests are required if the intraocular pressure (IOP) does not fall within the normal range or if the ocular nerve, which transmits visual information from our eyes to the brain, seems aberrant.

2. LITERATURE REVIEW:

Prevalence of primary open angle glaucoma in the last 20 years: A meta-analysis and systematic review:

POAG (primary open-angle glaucoma) is a main cause of permanent blindness worldwide, and it is impacted by a variety of sociodemographic variables. The goal of this meta-analysis is to assess the global prevalence of POAG in the adult general population during the past 20 years, as well as to investigate variation in frequency by age, gender, and geographic location. A search of the electronic literature was conducted using the databases PubMed, Embase, and Web of Science. POAG prevalence was reported in population-based cross-sectional or cohort studies published in the recent 20 years

(2000-2020). Meta-analysis was used to find and assess relevant papers that matched established eligibility criteria. POAG prevalence was examined in relation to several risk variables. The meta-analysis used a random effect model. This meta-analysis comprised fifty papers with a total of 198,259 participants. The global prevalence of POAG was 2.4% (95% CI 2.0 2.8%). The incidence rises with age. POAG is observed to be more prevalent in males than in women (RR 1.28, p 0.01). Among all continents, Africa has the greatest frequency of POAG (4.0%). POAG's current worldwide population is predicted to be 68.56 million (95% CI 59.99 79.98). POAG is a global vision-threatening condition that has been increasing in incidence over the past 20 years. Because of differences in risk variables like as age, gender, and population geographic location, the population-based prevalence of POAG varies greatly between different research.

Epidemiology of glaucoma: The past, present, and predictions for the future:

Glaucoma is a multifactorial visual degenerative neuropathy marked by ganglion cell loss in the retina. It is caused by a confluence of vascular, genetic, anatomical, and immunological variables. Glaucoma is a major public health problem since it is the second greatest cause of blindness after cataracts, and it is typically permanent. Primary open-angle glaucoma affects an estimated 57.5 million individuals globally (POAG). People over the age of 60, family relatives of those who have already been diagnosed with glaucoma, steroid users, diabetics, and those with severe myopia, hypertension, a central cornea thickness of 5 mm, and eye damage are all at greater risk of glaucoma. Glaucoma is anticipated to affect around 76 million individuals by 2020, with that figure expected to rise to 111.8 million by 2040. In this paper, we conduct a thorough literature analysis concentrating on the epidemiology of glaucoma and attempt to estimate the number of persons afflicted; we classify them based on gender, region, and economic level. Furthermore, we attempt to predict the illness's future projection in the following 20 years (2040) while estimating the disease burden, which includes the expense of treating and preventing the disease, as well as the disease and disability forecast of glaucoma.

Glaucoma clinical research: Trends in treatment strategies and drug development:

To study trends and advancements in glaucoma research, two major clinical trial registries were searched: clinicaltrials.gov and Australianclinicaltrials.gov.au. Methods: All glaucoma clinical studies listed on Clinicaltrials.gov and Australianclinicaltrials.gov.au that began before January 1, 2021 were included. Glaucoma treatment studies were isolated from non-treatment trials and classified into three broad categories: "laser therapy," "surgical treatment," and "medical treatment." New compounds and their particular targets were found in the "medical therapy" category and subcategorized according to therapeutic strategy: intraocular pressure (IOP)-lowering, neuroprotective, or vascular. The success rates of phase transitions were computed. One thousand five hundred and thirty-seven trials were found. Sixty-three percent (n = 971) considered glaucoma therapy, with medical treatment accounting for the majority (53%). The bulk of medical studies looked at IOP-lowering drugs, with just 5 and 3% looking at neuroprotective or vascular medicines, respectively. A total of 88 novel compounds were discovered. The success rates for phase I, II, and III transitions were 63, 26, and 47%, respectively. Conclusion: Over the past 30 years, the number of clinical studies in glaucoma research has expanded dramatically. All three major treatment techniques were represented among the most recently reviewed substances, although clinical studies in neuroprotection and vascular modalities remain few. Aside from conventional medications, nutritional supplements and growth factors are being studied for their possible anti-glaucoma impact. The success rates in phases II and III were lower than previously reported for all illnesses and ophthalmology in general. Stricter phenotyping of patients may increase glaucoma and ophthalmological research success rates and provide a better knowledge of responders and non-responders.

Beyond wearables and implantables: A scoping review of insertable medical devices:

The goal of this paper is to offer a definition for insertables, a novel class of in-body medical devices that are situated in the superficial skin layers; to give an overview of their technical capabilities and limitations; and to describe existing uses and prospective future use cases. Methods: To develop a knowledge of insertables and find their therapeutic uses, an unsystematic scoping study was done. Several sources of information were utilised, including peer-reviewed scientific publications, market research reports, and the Derwent Innovation intellectual property database. An examination of currently available insertables as well as those in development was carried out. Results: Insertables should have the following characteristics: I non-invasiveness; ii) simplicity of application, placement, and removal; iii) multi-functionality; iv) a flexible in-body life-span; and v) patient friendliness. There were 19 insertables found, with applications ranging from heart monitoring to continuous glucose monitoring to medication administration. A dozen insertables are scheduled to hit the market in the near future, with applications ranging from analyte detection to electroencephalogram monitoring and intraocular pressure assessment. Insertables combine the benefits of implantables and wearable medical devices into a single product. Insertables offer the ability to provide clinically valuable, dependable physiological data and treatment while causing little pain and danger to patients.

Clinical characteristics and current treatment of glaucoma:

Glaucoma is a neurological condition that causes substantial visual loss due to degenerating retinal ganglion cells (RGC). Glaucoma is a clinical term that refers to a group of diseases characterised by variable intraocular pressure (IOP) that lead to RGC loss by mechanical stress, vascular abnormalities, and other processes such as immunological events. Glaucoma is clinically diagnosed by assessing the ocular anterior segment using slit lamp biomicroscopy, which enables the physician to spot symptoms of diseases that might cause excessive IOP. Following IOP measurement, a gonioscope, a specialised prismatic lens, is used to assess if the angle is physically open or closed. Optic nerve head atrophy and excavation of the neuroretinal rim tissue are structural manifestations of RGC loss. When feasible, treatment is directed by treating secondary causes of increased IOP (such eye inflammation, infection, and ischemia). Following that, a range of medicinal, laser, and surgical methods are employed to obtain the desired IOP.

3. METHODOLOGY

Glaucoma is an irreversible neurological disease characterised by increased aqueous fluid and obstruction of the drainage route between the iris and cornea, resulting in intraocular pressure. As a consequence, the optic nerve head, which transmits vision information from our eyes to the brain, is injured, resulting in visual field loss and, eventually, blindness. Glaucoma is known as the "silent thief of vision" since it is difficult to detect early, and frequent screening is strongly advised to identify the neurological illness. Glaucoma detection is costly and time-consuming, and not only is there always the chance of human mistake, but this detection technique is also reliant on the availability of resources (experienced ophthalmologists and expensive instruments).

Disadvantages:

1. Glaucoma detection is expensive and time-consuming.
2. Glaucoma is known as the "silent thief of eyesight" because it is difficult to detect early on.

Several deep learning algorithms were used to construct an automated glaucoma classification system in this study. First, a new private dataset of 634 colour fundus photos has been gathered and analysed by two eye experts from Bangladesh Eye Hospital, a paediatric ophthalmologist and a glaucoma and refractive surgeon. Following that, several deep learning models (EfficientNet, MobileNet, DenseNet, and GoogLeNet) were employed to identify glaucoma in fundus pictures.

Advantages:

1. The model with the EfficientNet-b3 architecture outperformed the others in terms of test accuracy, F1-score, and ROC AUC.
2. This promising finding implies that blood vessel segmentation of fundus pictures might be used to identify glaucoma automatically.

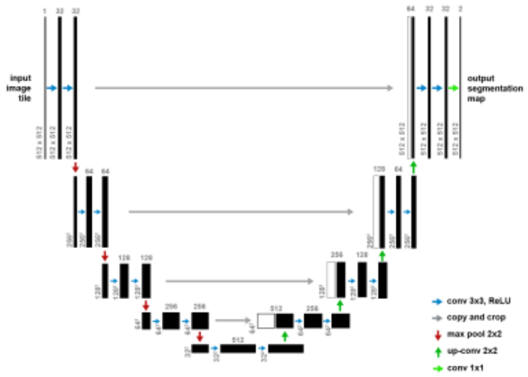

Fig.2.1: System architecture

MODULES:

To carry out the aforementioned project, we created the modules listed below.

- Data exploration: We will load data into the system using this module.
- Processing: We will read data for processing using this module.
- Splitting data into train and test: We will divide data into train and test using this module.
- Model generation: We will build the model using DenseNet, Inception ResNetV2, CNN, MobileNet, EfficientNetB3, and GoogleNet. Calculated algorithm accuracy
- User signup and login: Using this module will result in registration and login.
- User input: Using this module will result in prediction input.
- Prediction: the final predicted value will be presented.

4. RESULT / FINDINGS:

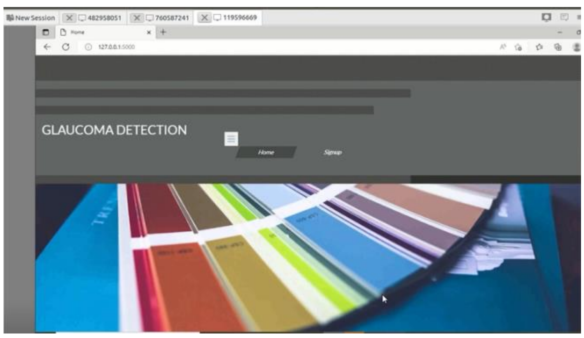

Fig.4.1: Home screen

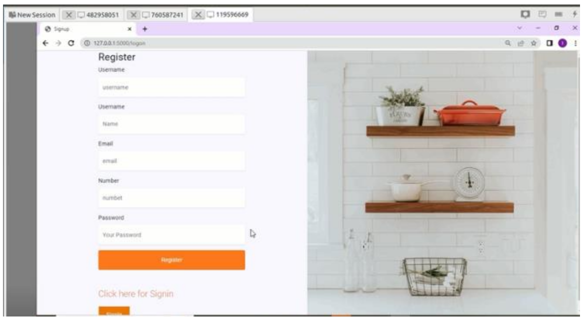

Fig.4.2: User signup

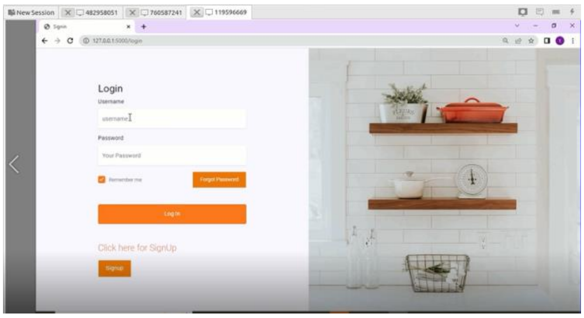

Fig.4.3: User signin

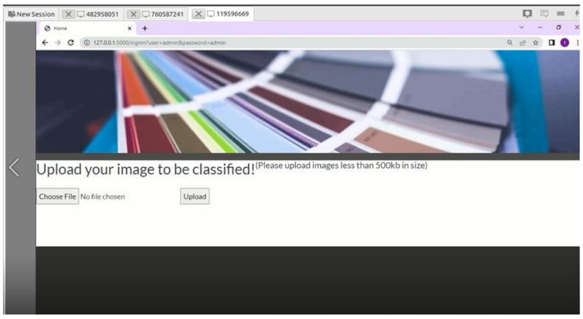

Fig.4.4: Main screen

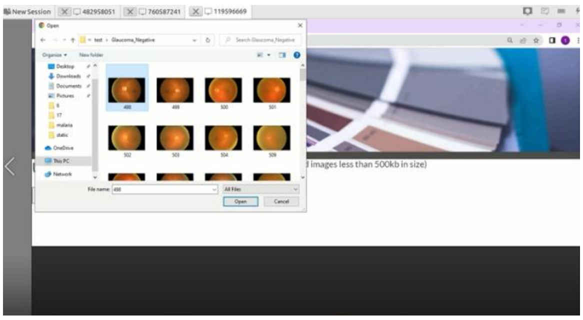

Fig.4.5: User input

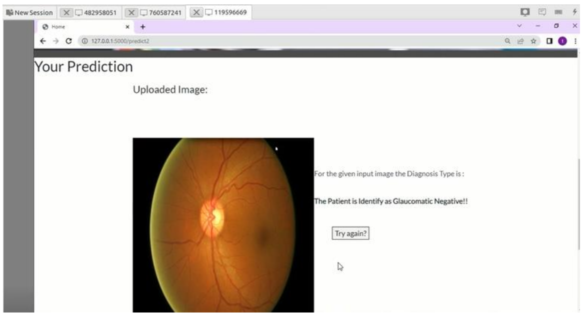

Fig.4.6: Prediction result

5. DISCUSSION/ ANALYSIS:

The **Innovative Glaucoma Diagnosis Using Cropped Optic Regions with Deep Learning Models** is a modern method that uses artificial intelligence (AI) to detect glaucoma. It focuses on analyzing the optic nerve area in eye images to identify signs of the disease.

Key Highlights:

- **Deep Learning**: AI models are trained to automatically detect glaucoma, making diagnosis faster and more accurate.
- **Cropped Optic Regions**: Only the important part of the image, the optic nerve, is used to improve the focus and reliability of the detection.
- **Challenges**: Issues like low-quality images and differences in eye structure can affect accuracy.
- **Impact**: This method can help in early detection of glaucoma, preventing vision loss through timely treatment.

It offers a smart, technology-driven way to improve eye care and save sight.

6. CONCLUSION / SUMMARY:

Glaucoma is an irreversible neurological disease that causes vision loss and blindness by damaging the optic nerve. The traditional manual identification of glaucoma by eye specialists is expensive and time-consuming, relying on human error, expert ophthalmologists, and pricey tools. This research seeks to create a deep learning-based automated glaucoma detection system. This research makes use of a private dataset that includes 463 normal (nonglaucoma) and 171 glaucoma colour fundus pictures taken from Bangladesh Eye Hospital (BEH) in Dhaka. These private and public ACRIMA datasets were used to create a collection of cropped fundus pictures that included the optic cup and disc part. A U-net model trained on the High-Resolution Fundus (HRF) Image Database is used to produce cropped and blood vessel segmented fundus pictures. Finally, as glaucoma classifier networks, many CNN techniques, including as MobileNet, EfficientNet, DenseNet, and GoogLeNet, have been applied. The EfficientNet b3 model performs best for cropped fundus pictures, with accuracy and ROC AUC values of 0.9652 and 0.9512, respectively. Alternatively, for blood vessel segmentation fundus pictures, the MobileNet v3 network has the greatest accuracy and ROC AUC. The suggested system's remarkable findings are expected to help ophthalmologists check and identify glaucoma more rapidly and affordably. The suggested method may be improved in the future by training with new data, including public and private eye fundus photos, and including synthetic images. The suggested technique and images of the eye fundus may be used to identify more complicated ocular illnesses such as diabetic retinopathy, age-related macular degeneration (AMD), and amblyopia. The glaucoma colour fundus photos and programming code implementations from Bangladesh Eye Hospital (BEH) may be obtained at:

https://github.com/mirtanvirislam/Deep-Learning-BasedGlaucoma-Detection-with-Cropped-Optic-Cup-and-Discand-Blood-Vessel-Segmentation.

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