**Introduction**

**1.1 Glaucoma: A Silent Threat to Vision**

Glaucoma is a group of eye diseases that damage the optic nerve, the pathway that transmits visual information from the eye to the brain. This damage is often caused by abnormally high pressure within the eye (intraocular pressure or IOP). Glaucoma is a leading cause of irreversible blindness, particularly for people over 60 years old. The insidious nature of glaucoma lies in the fact that it often progresses gradually without any noticeable symptoms in the early stages. By the time vision loss becomes apparent, the damage may be significant. (Križaj)

**1.2 Fundus Imaging: A Window into Eye Health**

Fundus imaging, also known as retinal photography, is a non-invasive diagnostic technique that captures a detailed picture of the back of the eye, including the retina, optic nerve, and blood vessels. This imaging technique plays a crucial role in diagnosing glaucoma. (Davis) By examining the fundus image, ophthalmologists can identify specific changes associated with glaucoma, such as damage to the optic nerve head and thinning of the retinal nerve fiber layer. Early detection of these changes is vital for initiating treatment and preventing vision loss. (Bussel)

**1.3 Motivation: AI for Early Glaucoma Detection**

Despite the effectiveness of fundus imaging for glaucoma diagnosis, the process can be time-consuming and subjective. Highly trained ophthalmologists are required to interpret the subtle changes in the images. (Mursch-Edlmayr) This project aims to address these limitations by exploring different **artificial intelligence (AI) models** that can analyze fundus images and assist in **early detection of glaucoma**. By leveraging the power of AI, we hope to make some aspects of glaucoma diagnosis, leading to faster, more objective, and potentially more accessible screening for this sight-threatening disease. (Mursch-Edlmayr)

**Literature Review: Detecting Glaucoma with Technology**

Traditionally, ophthalmologists diagnose glaucoma by examining a patient's eye and reviewing **fundus images**. These images capture the back of the eye, revealing the optic nerve and other structures. However, new technologies are emerging to assist in this process.

**1. Existing Methods:**

* **Visual Inspection:** Highly skilled ophthalmologists can identify signs of glaucoma in fundus images, such as changes in the optic nerve shape or thinning of the retinal nerve fiber layer. This method, however, is subjective and time-consuming.
* **Image Processing Techniques:** Computer algorithms can analyze fundus images for specific features linked to glaucoma. These techniques may involve measuring the **cup-to-disc ratio** (ratio of the optic cup size to the entire optic nerve) or detecting specific patterns in the blood vessels. While offering some automation, these methods may not capture the full complexity of the disease. (Schuster)

**2. Advantages and Limitations:**

**Traditional methods** are reliable when performed by experienced professionals. However, they can be **subjective, time-consuming, and prone to human error**. (Bettin)

**3. Machine Learning to the Rescue?**

**Machine learning (ML)** offers new possibilities for glaucoma detection. ML algorithms can be trained on large datasets of fundus images labelled as healthy or glaucomatous. These algorithms can then learn to identify patterns in the images that are associated with the disease.

**Recent research** has explored various ML approaches, including:

* **Deep Learning:** A subfield of ML, deep learning utilizes artificial neural networks with many layers to learn complex features directly from data. Studies have shown promising results using **Support Vector Machines (SVMs),** **Convolutional Neural Networks (CNNs), Tensorflow and PyTorch** for glaucoma detection due to their ability to analyze image patterns.

**Advantages of ML methods:**

* **Potential for faster and more objective analysis** compared to traditional methods.
* **Ability to learn complex patterns** in fundus images that may be difficult for humans to detect.

**Limitations of ML methods:**

* **Reliance on high-quality training data:** The accuracy of ML models depends on the quality and size of the data they are trained on.
* **Need for further validation:** While promising, ML models for glaucoma detection require further validation on large and diverse datasets before widespread clinical use.

**Methodology: Exploring and Comparing AI Models for Glaucoma Detection**

To explore and compare different AI models for glaucoma detection, we followed a specific approach:

**1. Data Preparation:**

* **Dataset Source:** We utilized a publicly available Kaggle dataset of fundus images specifically designed for glaucoma research.
* **Data Size and Composition:** The dataset contained a some of number of images, with approximately 5293 healthy eyes and 3328 eyes diagnosed with glaucoma for training set, 1774 healthy eyes and 1120 eyes diagnosed with glaucoma for testing set and 3539 healthy eyes and 2208 eyes diagnosed with glaucoma for validation set.
* **Pre-processing:**
  + **Anonymization:** To protect patient privacy, any identifying information was removed from the images.
  + **Standardization:** Images were resized to a uniform size to ensure compatibility with the AI model.
  + **One of the Datasets was already processed data we did not spend much more time and resources on that.**

**2. AI Models:**

* **Using Tensor-flow:** TensorFlow is a versatile open-source deep learning framework developed by Google. It provides a comprehensive set of tools and functionalities for building, training, and deploying various machine learning models, including CNNs for image analysis. We considered using TensorFlow for our project due to its advantages such as:
* **Extensive Ecosystem:** TensorFlow boasts a large and active community, offering a wealth of resources, tutorials, and pre-trained models.
* **Scalability:** TensorFlow can be scaled to run on various hardware platforms, from single machines to large-scale distributed systems.
* **Flexibility:** It supports various programming languages (Python, C++, Java) and allows for customization of the training process.
* **Using Pytorch:** PyTorch is another popular open-source deep learning framework, known for its ease of use and flexibility. It offers a Python-first approach and provides intuitive tools for building and training neural networks. We considered using PyTorch for our project due to its strengths like:
* **Readability:** PyTorch code is often considered more readable and user-friendly compared to TensorFlow.
* **Ease of Debugging:** PyTorch offers debugging functionalities that can streamline the development process.
* **Active Research Community:** PyTorch is backed by a strong research community, constantly evolving and introducing new features.

**3. Training:**

* **Optimization Algorithm:** We trained 3 models on dataset
  + **VGG16**
  + **Efficientnet**
  + **Resnet**
* **Training Difficulties:** As we are still in learning phase, to train model on dataset is such a challenging. But we tried our best to do so. Due to heavy algorithms we also faced some running issue because model needs some GPUs to work on data, so we started hunting for different platform that provide us accessible GPU/TPU:
  + **Kaggle**
  + **CoLab**
  + Own local machine

But there were other issues of using machines on those platforms such as limited time access, on Colab 25-30 minute per day and on Kaggle 15-20 hours per week, another problem was that the most recent research paper are paid to access so we could not study the most recent research on this topic, limited dataset is one of the issues that we faced because most of the datasets are expensive to access in term of money and space both, more than 30 GBs data it take, and they are highly paid in Euros and dollars.

**Results: Which Algorithm Performed well?**

Evaluating the performance of AI models for glaucoma detection is crucial. We used several key metrics to assess its effectiveness:

* **Accuracy:** This metric reflects the overall percentage of images the model classified correctly (healthy or glaucomatous).
* **Sensitivity:** This metric indicates how well the model identified glaucomatous images (true positive rate). A high sensitivity is important to avoid missing cases of glaucoma.
* **Specificity:** This metric reflects how well the model correctly classified healthy images (true negative rate). A high specificity is important to minimize false positives (healthy eyes identified as glaucomatous).

**Performance on Test Data:**

We evaluated these models’ performance on a test part of our dataset not used during training. This helps ensure the model generalizes well to unseen data. We will report the following:

* **Visualizations:** We'll include a confusion matrix to visualize the distribution of correct and incorrect classifications (true positives, true negatives, false positives, false negatives).

**Strengths and Weaknesses:**

By analyzing the results, we can discuss the strengths and weaknesses of different AI models:

* **Strengths:** If a model achieves high accuracy, sensitivity, and specificity as compare to other models, we can highlight its effectiveness in accurately classifying healthy and glaucomatous images. In our project the best Model is ResNet50 with the accuracy of 88%.
* **Weaknesses:** If the model shows limitations in any metric or accuracy is less in comparison of other model then, this thing will be count as Weakness of Model. In our project the Weak model is EfficientNet with the Accuracy of 60%. This model is weak according to our work because this model shows all the result in only True Positive values and False Negative values. It does show 0 Zero result for True Negation and False Positive.

**Discussion: Putting the Results in Perspective**

**1. Comparing AI models with Existing Research:**

We have interpreted our models’ performance in the context of existing research on AI-based glaucoma detection, existing Accuracy according to (Diaz-Pinto) is 95% to 97% on VGG16 model and according to us it has been 72% to 79%. For the model ResNet50 we achieved the accuracy of 85% to 89% where (Shoukat) has shown the accuracy up to 99.2%. For EffientNetB0 there is no any research available but according to our 62% with 0 false positive and 0 true positive values means this did not perfect good.

**2. Potential Clinical Implications:**

If our work demonstrates promising results, we can explore its potential clinical implications:

* Improved Efficiency: AI could potentially assist ophthalmologists in analyzing a larger volume of fundus images, enabling faster screening for glaucoma.
* Enhanced Objectivity: AI systems can offer a more objective analysis compared to traditional methods, potentially reducing inconsistencies in diagnosis.
* Early Detection: By automating some aspects of image analysis, AI could contribute to earlier detection of glaucoma, leading to more timely treatment and potentially improved patient outcomes.

**3. Limitations of Our Study:**

No research is perfect, and it's important to acknowledge the limitations of our study:

* Dataset Size: The size and composition of the dataset we used can impact the model's generalizability. A larger and more diverse dataset might improve performance.
* Model Complexity: The chosen PyTorch architecture might not capture all the intricacies of the disease. Exploring alternative architectures or incorporating additional data modalities (e.g., patient information) could be future directions.
* Clinical Validation: While our results are promising, extensive clinical validation with real-world patient data is crucial before AI systems can be implemented in clinical practice.

Addressing these limitations demonstrates a critical and comprehensive understanding of your research. It also paves the way for future improvements and highlights the need for further research before widespread clinical adoption.

**Conclusion**

In this project, we compared different AI models for glaucoma detection using fundus images. Here's a summary of our key findings:

* **AI Model Performance:**
  + **Resnet50**: In this model Accuracy while training: 80% and 88% on testing.
  + **VGG16**: In this model Accuracy while training: 72.5% and 79% on testing.
  + **EfficientNetB0**: In this model Accuracy while training: 62.2% and 61% on testing.

**Potential Impact:**

Despite any limitations, AI models has the potential to:

* **Improve Efficiency:** By assisting ophthalmologists in analyzing fundus images, the AI could expedite glaucoma screening.
* **Enhance Objectivity:** The system could potentially offer a more objective analysis compared to traditional methods.
* **Early Detection:** AI-assisted analysis could contribute to earlier detection of glaucoma, leading to better patient outcomes.

**Future Directions:**

Here are some potential future directions:

* **Exploring Model Architectures:** Experimenting with different CNN architectures or other deep learning models might improve performance.
* **Incorporating Additional Data:** Including patient information like demographics or intraocular pressure data could enhance the model's accuracy.
* **Clinical Validation:** Extensive testing with real-world patient data is crucial before clinical implementation.

By addressing these limitations and pursuing further research, we can strive to make AI-based glaucoma detection systems even more reliable and impactful in clinical settings.

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Project name:

AI-Based Glaucoma Detection Using Fundus Images.

Dataset:

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