Harnessing Vision AI for Automated

Classification of Intracranial Aneurysms

PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report "Harnessing Vision AI for Automated Classification of Intracranial Aneurysms " is the Bonafide work of "Mr. Bipin Kumar, Mr. Harsh Raj, Mr. Prince Kumar, and Mr. Gulshan Kumar" who carried out the project under my supervision.

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Bipin Kumar | Harsh Raj

Prince Kumar | Gulshan Kumar

Overview

This project focuses on using machine learning to help doctors predict the risk of brain aneurysms rupturing. A brain aneurysm is a weak spot in a blood vessel in the brain that can swell like a balloon. If it bursts, it can cause serious health problems or even death. Often, aneurysms don't show any symptoms until they rupture, making it hard to detect the danger early.

The main goal of the project is to create a tool that gives doctors early warnings about high-risk aneurysms. To do this, the model analyzes medical images like CT scans, MRIs, or angiograms. It also looks at important patient details such as age, medical history, and specific features of the aneurysm, like its size, shape, and location. By combining this information, the model can predict the likelihood of an aneurysm rupturing.

Several machine learning methods were tested, including Logistic Regression, Random Forest, SVM, XGBoost, Decision Tree, and Deep Learning models. Among these, Logistic Regression performed the best, achieving an accuracy of 85.71%. This makes it a reliable tool for helping doctors make decisions.

This project has the potential to improve patient outcomes significantly. By identifying high-risk aneurysms early, doctors can take timely action, such as monitoring the patient more closely or recommending preventive treatments. This could prevent life-threatening complications and save lives.

In the future, the model can be further improved by including more data and exploring additional factors, such as other health markers that might indicate a higher risk of rupture. Overall, this project demonstrates how technology can support medical professionals and enhance patient care.

Contents

Chapter 1

Introduction

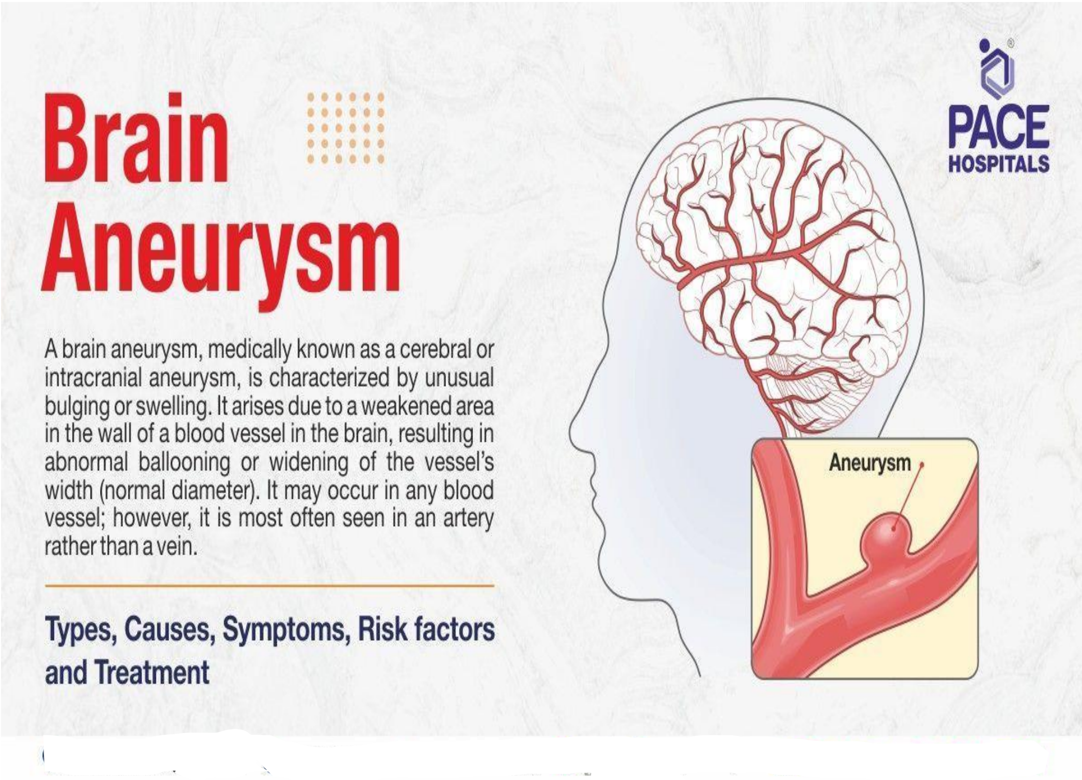
Understanding Brain Aneurysms
Brain aneurysms are a serious health risk that occur when a weak spot forms in a blood vessel in the brain, causing it to bulge out like a balloon. If this bulge bursts, it can result in severe bleeding, brain damage, or even death. What makes aneurysms especially dangerous is that they often show no symptoms until they rupture.

This project focuses on a protein called **NF-κB**, which might play a key role in the formation of aneurysms. NF-κB is known to cause inflammation in the walls of blood vessels. Inflammation can weaken the vessel walls, increasing the risk of aneurysms forming or bursting.

To understand this better, we are reviewing past studies where researchers blocked NF-κB in animal models. These studies showed that reducing NF-κB activity led to less inflammation and stronger blood vessels. Inspired by these findings, our project aims to find safe ways to reduce NF-κB activity in humans, particularly in high-risk groups like smokers or those with high blood pressure.

Exploring Solutions to Prevent Aneurysms

The primary goal of this project is to explore how reducing NF-κB activity can prevent aneurysms. Drugs that target NF-κB might offer a promising solution for people at high risk. By limiting the protein's activity, we hope to reduce inflammation, strengthen blood vessels, and lower the chances of aneurysms forming or rupturing.
In addition to drug research, we are leveraging **AI and deep learning technologies** to improve early detection. AI models are being trained to analyze brain scans and identify subtle patterns associated with aneurysms. This advanced technology can act as an early warning system for doctors, helping them take action before a rupture occurs.



Our Vision: Combining Research and Technology

By combining scientific research on NF-κB with cutting-edge AI tools, this project aims to revolutionize the way aneurysms are prevented and treated. Our vision includes:

1. **Safer Drug Solutions**: Developing medications that reduce NF-κB activity to prevent aneurysms in high-risk individuals.

2. **AI-Driven Early Detection**: Creating an AI system that can quickly and accurately detect aneurysm risks from brain scans.

This dual approach could significantly improve patient outcomes. Early detection enables timely intervention, while drug research paves the way for long-term prevention. Our ultimate goal is to make brain aneurysm treatment smarter, faster, and more effective, ensuring that patients can live healthier and safer lives.

Chapter 2

Basic Concepts/ Literature Review

In this project, we will be exploring how a protein called NF-κB might lead to brain aneurysms. A brain aneurysm occurs when a blood vessel in the brain develops a weak spot that can start to bulge out, and if it bursts, it can lead to serious bleeding. NF-κB play an important role in causing inflammation like swelling and irritation, in the walls of blood vessels.

This can make the vessel walls more weaker and increase the chances of an aneurysm forming or breaking. To better understand this, I'll start by reviewing past studies where NF-κB was blocked in animals to see if it could stop aneurysms from forming or bursting. In these studies, reducing NF-κB activity also reduced inflammation and kept the blood vessels stronger. Based on this, I'll look at ways to safely block NF-κB in humans, like testing certain drugs that might decrease its activity. This could be especially helpful for people at higher risk, such as those who smoke or have high blood pressure. The main goal of this project is to find ways to prevent aneurysms by targeting NF-κB, which could help keep blood vessels strong and reduce the risk of aneurysms forming or becoming serious.

In this project, I'm studying new ways to help treat brain aneurysms. A brain aneurysm is like a small bulge in a blood vessel in the brain. If this weak spot bursts, it can cause very serious bleeding and be life-threatening. There are two main ways to treat aneurysms: surgery and a method called endovascular therapy. In surgery, doctors place a small clip on the aneurysm to block blood flow so it won't burst. Endovascular therapy is different because it treats the aneurysm from inside the blood vessel.

Doctors insert tiny coils or stents to help seal off the aneurysm. Many hospitals now prefer endovascular therapy, especially because new tools like flow diverters and the Woven EndoBridge (WEB) have made it more effective. These tools block blood flow to the aneurysm, which helps it shrink over time. In the future, researchers hope to use artificial intelligence to help doctors find aneurysms faster and choose the best treatment for each and every patient.

Through this project, I'll be focusing on how these new devices and AI might make it easier to prevent aneurysms from bursting, making treatment safer and more effective. The main goal is to keep blood vessels strong and reduce the risks of aneurysms becoming dangerous.

The research talks about brain aneurysms, that are areas in the blood vessels of the brain that act as weakened areas and appear as bulb-like protrusions. Even though most do not break open, such a scenario when it breaks open can result in severe harm or death. Early aneurysm detection is crucial because risk accompanies treatment that may, in some instances, be larger than the threat of an aneurysm.
The blood creates sounds as it moves through the bulge; scientists aim to ascertain whether these noises and oscillations can foresee whether or not an aneurysm will break open. Using high-technology computer modeling, the researchers were able to recreate the wall vibrations of aneurysms from blood flow. The study involved six cases of aneurysms to find how blood flow interacts with such aneurysms. In five of them, the blood flow was turbulent, giving rise to both random vibrations, known as "bruits," and specific musical sounds known as "murmurs." In one case, the flow was smooth, with no vibrations found.
All of the results fit earlier records made of aneurysm sounds and may mean such vibrations would weaken the aneurysm walls themselves. The study findings may allow doctors to find potentially dangerous aneurysms by listening for these specific sounds, meaning they would be able to make more informed decisions about treatments. Future research will possibly investigate how these vibrations actually impact the walls of the arteries, and there could be safer and even more precise methods of discovery and treatment of aneurysms.

This is the use of AI to automatically identify intracranial aneurysms in brain scans, meaning using a computer program to detect weak or bulging spots in blood vessels within the brain. The aneurysm can be very important to detect early because if they rupture, they can cause significant harm or even death. Traditionally, doctors identify aneurysms by closely examining the images from a CT angiography (CTA) scan. A CTA scan shows the blood vessels in the brain. The problem with detecting aneurysms is that most of the small ones are mostly not easily detectable and also error-prone. Vision AI, generated by deep learning, can scan those brain scans at phenomenal speeds and accuracy. Deep learning is an artificial intelligence used to train a computer by showing it thousands of examples so that the machine "learns" what patterns are. So, thousands of pictures of aneurysms are fed into this AI system so that the system can learn to recognize even the tiniest or most obscure 'blips'. For instance, it may classify based on size, shape, or risk level so that a doctor can figure out what needs immediate intervention. The positive side of Vision AI is that it can be run continuously, especially to help doctors reduce their workload and minimize errors. Sensitivities can increase up to 87% for detecting larger aneurysms using deep learning; however, smaller ones, such as those less than 3 mm are still hard to find. There's still room for improvement to make the systems even better at catching the smallest details. This technology is promising for soon being applied in the hospitals to enable doctors to make aneurysm detectable faster, thus save more lives by finding more aneurysms prior to causing a problem. Researchers are trying to improve the precision on smaller aneurysms, standardize how AI testing methods are, and collect more data, which will ensure reliable findings across hospitals and equipment

Chapter 3

Problem Statement / Requirement Specifications

Brain aneurysms are often silent and difficult to detect, but when they rupture, the consequences can be life-threatening. Our goal is to create a machine-learning tool that helps doctors predict which aneurysms are at the highest risk of rupture. By analyzing a patient's medical images (such as CT scans, MRIs, or angiograms) along with important details like their age, medical history, and the specific characteristics of the aneurysm (like size, shape, and location), the model can provide doctors with insights to make informed decisions. This early warning system could enable timely interventions, improving patient outcomes and potentially saving lives by preventing catastrophic ruptures

3.1 Project Planning

Understand Aneurysms
Learn how they form and what factors, like inflammation caused by a protein called NF-κB, contribute to their development.

Improve Detection
Use AI to scan brain images and find aneurysms more quickly and accurately than humans can. This could help doctors act faster.

Create Better Tools
Use the data we collect to design systems that predict the risk of aneurysms rupturing, guiding better treatment decisions.

Chapter 4

Implementation

In this section, present your implementation during the project development.

4.1 Methodology

1. Preparing the Data (Data Preprocessing)

Think of this as cleaning up and organizing your workspace before starting a big project. We'll gather all the necessary patient information—like brain scans and medical histories—and get it ready for the AI to learn from.

- We'll tidy up the images so they're clear and consistent, kind of like making sure every piece of a puzzle fits together perfectly.
- Then, we'll mark the areas that show aneurysms (tiny bulges in blood vessels) to help the AI know what to look for.
- If anything's missing or unclear, we'll fill in the gaps or leave out anything unnecessary, so the data is as useful as possible.

2. Teaching the AI (AI Model Development)

This step is like training a new employee—you show them the ropes, correct their mistakes, and help them get better over time.

- We'll create a smart system (called a deep learning model) that learns to spot aneurysms from brain images, even the ones that are really small or tricky to see.
- To train it, we'll give it lots of examples with clear labels, like "This is an aneurysm" or "This is normal."
- We'll also make sure it practices with a variety of examples, so it doesn't get thrown off by things like blurry images or different angles.

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3. Checking the AI's Work (Evaluation Metrics)

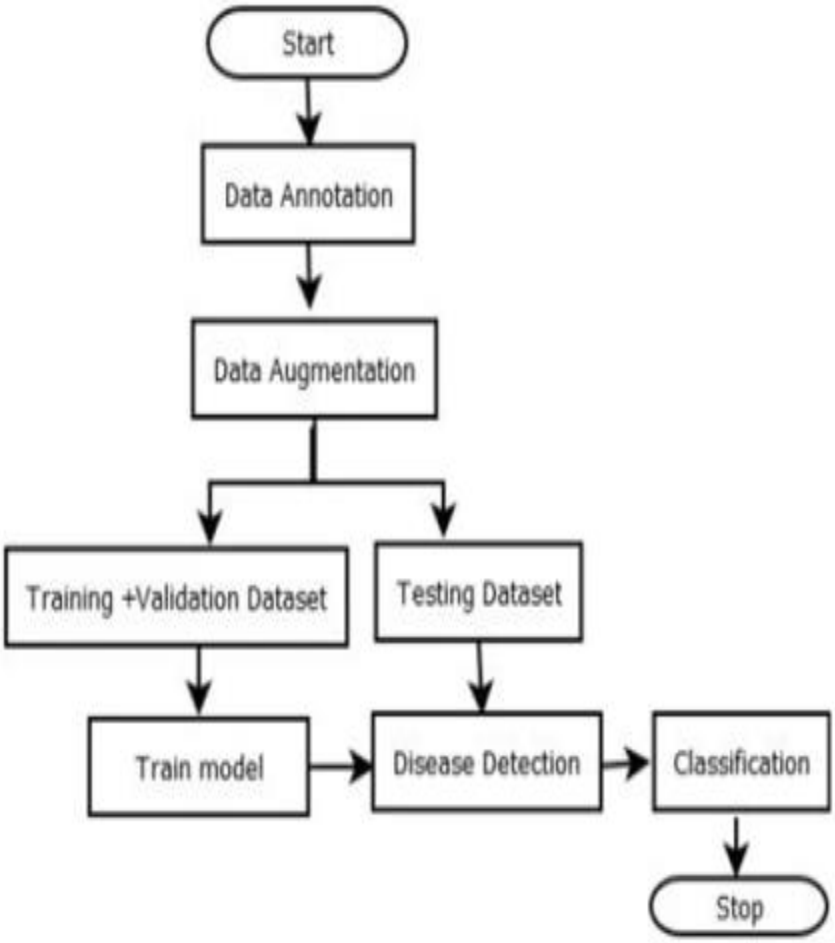
Once the AI is trained, we need to see how well it's doing—like grading a test.

- We'll check how good it is at finding aneurysms without missing any (sensitivity) and how well it avoids false alarms (specificity).
- If it's making mistakes, we'll analyze why and help it improve. For example, we'll look at cases where it didn't spot an aneurysm or marked something normal as abnormal.
- Finally, we'll test it on completely new data to make sure it works well outside of training.

4. Making It Useful (Integration)

Here’s where we connect everything and make sure the tool actually helps doctors and patients.

- We’ll combine what the AI finds with other important details, like the patient’s health history or biological clues, to get a clearer picture of the risk.
- Then, we’ll make the results easy to understand, so doctors can see exactly what the AI found and why it matters. Imagine it like a weather forecast for the brain: clear visuals and straightforward explanations
- Finally, we’ll make sure this tool fits into the busy workflows of hospitals, helping doctors make faster, more accurate decisions.



4.2 Result Analysis

```
              precision    recall  f1-score   support

       False       0.86      1.00      0.92        18
        True       1.00      0.00      0.00         3

    accuracy                           0.86        21
   macro avg       0.93      0.50      0.46        21
weighted avg       0.88      0.86      0.79        21

Logistic Regression Accuracy: 0.8571428571428571
Random Forest Accuracy: 0.8095238095238095
SVM Accuracy: 0.8095238095238095
XGBoost Accuracy: 0.8571428571428571
Decision Tree Accuracy: 0.8095238095238095
Deep Learning Accuracy: 0.8571428571428571

Best Model: Logistic Regression with accuracy 0.8571428571428571
```

Summary of Result Analysis for Brain Aneurysm Detection

Classification Report:

The True class (indicative of multiple aneurysms) has a precision of 1.00 but a recall of 0.00, leading to an F1-score of 0.00. This indicates the model is unable to correctly predict the minority class despite its high precision.

The False class has high precision (0.86) and recall (1.00), resulting in a robust F1-score of 0.92.

The macro average metrics reveal significant class imbalance, with a recall of 0.50 and an F1-score of 0.46, suggesting the model's limited effectiveness in handling both classes equally.

Model Performance:

Logistic Regression and XGBoost achieved the highest accuracy at 85.71%, followed by Deep Learning.
Other models like Random Forest, SVM, and Decision Tree delivered slightly lower accuracy of 80.95%.

Best Model Selection:

Logistic Regression is identified as the best-performing model due to its balance of simplicity and performance, achieving an accuracy of 85.71%

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

Why This Project Matters (Project Significance)

This project is all about bringing two powerful forces together: the latest in AI technology and cutting-edge biological research. By combining these, we're taking big steps toward solving a life-threatening problem—brain aneurysms.

1. **A Perfect Partnership Between Biology and AI**
   - We're not just teaching a computer to read brain scans; we're also using insights from biology to understand what causes aneurysms to form and rupture. By connecting these dots, we're building a smarter, more effective tool that goes beyond surface-level detection.
2. **Saving Lives Through Early Action**
   - Brain aneurysms are often called "silent killers" because they don't usually show symptoms until it's too late. With this AI, doctors can find them earlier—sometimes before they even become dangerous. That means more lives saved and fewer emergencies.
3. **Making Treatments Fit Each Person**
   - Not every aneurysm is the same. Some need urgent treatment, while others don't. By using AI to analyze the risk of rupture, doctors can decide on the best plan for each patient. This personalized care ensures people get exactly what they need—nothing more, nothing less.
4. **Helping Doctors Learn Even More**
   - This isn't just about creating a tool for today; it's also about advancing medical knowledge for tomorrow. The data we collect and analyze can help uncover new clues about why aneurysms happen and how to prevent them.

What's Next? (Next Steps)

We’ve laid the groundwork, and now it’s time to take this project out of the lab and into the real world. Here’s how we’ll make it happen:

1. **Testing the AI in Real Hospitals**
    - We’ll start by putting the AI to the test with real patients in hospitals. This means working side-by-side with doctors to see how well it detects aneurysms and how reliable its predictions are. It’s like giving the AI a “practice run” in the real world.
    - We’ll also watch closely to see where the AI might struggle, like with unusual cases, so we can make it even better.

2. **Working Hand-in-Hand with Doctors**
    - Doctors and medical teams will play a huge role in shaping this tool. They’ll test it, give us feedback, and help us make sure it’s easy to use and fits naturally into their busy schedules.
    - We’ll provide training so they feel confident using the AI, and we’ll listen carefully to their ideas on how to improve it further.

3. **Rolling It Out Step by Step**
    - Once we’ve tested and refined the AI, we’ll introduce it to more hospitals through pilot programs. Think of this as a gradual rollout where we make sure everything works smoothly before scaling up.
    - Over time, we hope this tool will be available in hospitals around the world, helping doctors save lives wherever they’re needed.

6.2 Future Scope

AI Development

We’re working to make the AI even smarter and more precise. Right now, the goal is to enhance its sensitivity so it can detect even the tiniest aneurysms—those that are easily missed by the human eye or traditional methods.

- **Why It Matters**: Smaller aneurysms might not seem like a big deal at first, but catching them early could mean preventing life-threatening complications down the line. By training the AI to spot these subtle signs, we’re giving doctors a powerful tool to act sooner.

- **How We’re Doing It**: Using advanced techniques like image enhancement and better training data, we’ll teach the AI to pick up on faint or irregular patterns that signal early-stage aneurysms. Think of it like improving a detective’s skills to notice even the smallest clues.

Clinical Integration

Getting the AI tool into hospitals and clinics is all about making sure it’s easy for doctors to use and consistent no matter where it’s deployed.

- **Why It Matters**: Healthcare settings are incredibly diverse—what works in one hospital might not work in another. Standardizing the tools ensures that the AI delivers the same high level of performance everywhere, whether it’s a small clinic or a major medical center.

- **How We’re Doing It**: We’ll work with medical professionals to develop clear guidelines and workflows for using the AI tool. This means creating user-friendly interfaces, integrating the system with existing hospital software, and ensuring it fits seamlessly into how doctors already work.

- **The Big Picture**: When standardized, this tool won’t just be a one-off innovation—it will become a reliable part of healthcare worldwide, helping patients regardless of where they’re treated.

Broader Research

The journey doesn't stop with aneurysms—we're pushing the boundaries of what we can learn and predict by using AI and biological research together.

1. **Validating Findings with Larger Datasets**
   - To make sure the AI is truly effective, we'll test it on larger and more diverse patient data from different hospitals, countries, and demographics.
   - This helps ensure that the tool works not just in controlled environments but also in the real world, across a variety of cases and conditions.
   - It's like taking a new product on a global test drive to ensure it performs well under all conditions.
2. **Finding New Predictors for Aneurysm Risks**
   - Beyond what we already know, we'll look for additional signals in the body—like specific proteins, genes, or inflammation markers—that might hint at an increased risk of aneurysm rupture.
   - By combining these biological indicators with AI's image analysis, we're creating a comprehensive system that can predict risks even before aneurysms become visible.
   - This could lead to a future where doctors can proactively monitor and treat patients at risk, rather than waiting for a problem to appear.

Why This Matters in Real Life

Imagine a world where no one has to suffer the surprise of a ruptured aneurysm because doctors have tools that can detect and predict risks far earlier. This project isn't just about technology or biology—it's about saving lives and giving people better, longer futures. By improving AI sensitivity, making it practical for everyday clinical use, and expanding what we know through research, we're laying the foundation for a healthcare revolution that benefits everyone.
Let me know if you'd like to expand on any specific part!

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