Abstract

Snakebite envenoming is a pressing public health emergency in South Asia, where treatment outcomes are critically dependent on rapid and accurate species identification. This project introduces **VenomGuard**, a novel diagnostic decision-support system designed to address this challenge. Its primary innovation is a resilient, multi-modal identification framework that offers three distinct diagnostic pathways: AI-powered image analysis, a guided questionnaire on physical characteristics, and an expert system for clinical symptom analysis. This ensures a reliable identification is possible even in high-stress situations with varied and often incomplete information.

The system is built on a hybrid architecture, combining a deep learning object detection model with a rule-based logic engine. The visual recognition module was trained on a comprehensive, augmented dataset of regional snake species, enabling it to discern subtle identifying features from a single photograph. The logic-based pathways are powered by a structured knowledge base that meticulously maps each species to its venom profile, key clinical syndromes, and medically-verified antivenom protocols.

Delivered through a clear and intuitive web-based interface, the system synthesizes user input from any of the three modules to generate an immediate and actionable diagnostic report. This report details the probable species, its venom characteristics, the recommended antivenom, and critical first-aid instructions, tailored for both the general public and healthcare professionals.

VenomGuard transcends the function of a simple identification tool; it serves as a critical bridge between the moment of crisis and the delivery of timely, appropriate medical care. By ensuring a diagnostic pathway is available whether a user has a clear photograph, a fragmented description, or only a set of patient symptoms, this project delivers an accessible and scalable solution. It demonstrates the profound potential of targeted technological innovation to save lives and enhance healthcare outcomes in underserved regions.

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Introduction

1.1 Overview

Snakebites are a critical public health issue, particularly in tropical and subtropical regions like Bangladesh and South Asia [1]. Each year, **approximately 4,00,000 individuals in Bangladesh suffer from snakebites**, leading to over **7,500 dead** [2]. According to a study titled "National Survey on Annual Incidence and Epidemiology of Snakebite in Bangladesh".

According to the study, these snake attacks result in 10.6% physical disability and 1.9% mental disability among the affected individuals [3].

Many victims face delayed or improper treatment due to a lack of accurate identification of the snake species responsible for the bite. This often results in the administration of generic antivenoms, which may be ineffective or suboptimal for treating bites from specific venomous snakes, thereby increasing fatalities and complications.

In recent years, incidents involving venomous snakes such as the Russell's viper have become more frequent, causing significant distress among rural communities in Bangladesh. For instance, **the alarming rise in Russell's viper attacks in 2024 highlighted the urgent need for an efficient and reliable system to identify snake species and recommend the correct antivenom** [2].

To address this pressing issue, our project, **Snake Antivenom Prediction Using Computer Vision and Automated Machine Learning, provides a robust solution**. By leveraging advanced technologies in computer vision and machine learning, the system predicts the name of the snake species based on uploaded images, textual descriptions, or patient symptoms. The primary objective is to assist medical professionals and healthcare workers in identifying the correct antivenom for the patient, thereby reducing treatment delays and improving survival rates.

Our project focuses on both local and regional applications, with the potential to expand globally. By creating an accessible and scalable tool, this innovation aspires to bridge the gap between snakebite treatment and accurate diagnosis, saving countless lives and improving healthcare outcomes in snakebite-prone regions.

1.2 Motivation

Snakebites are recognized as a neglected tropical disease by the World Health Organization (WHO), disproportionately affecting rural and underserved populations. The lack of immediate access to proper medical care, coupled with the limited availability of species-specific antivenom, often results in severe morbidity and mortality. In Bangladesh alone, venomous **snakebites claim more than 7,500** lives annually, with countless others left suffering from long-term complications. The situation is even graver when considering South Asia, which accounts for nearly 70% of global snakebite fatalities.

A major challenge in treating snakebite victims lies in accurately identifying the snake species responsible for the bite. In many cases, healthcare providers rely on common antivenoms that are broad-spectrum but less effective for specific snake venoms. This has led to higher mortality rates and adverse reactions due to incorrect treatment. The need for a reliable, easy-to-use system that can bridge the gap between snakebite diagnosis and treatment is therefore urgent.

Our motivation for this project also stems from recent alarming trends, such as the significant rise in **Russell's viper attacks** in 2024 in Bangladesh, which resulted in numerous fatalities and drew national attention to the issue. Additionally, anecdotal and statistical evidence highlights that rural farmer, herders, and even children are the most vulnerable groups, suffering not only physically but also economically from snakebite-related disabilities [4].

Figure 1.2.1: Russel's Viper

Through this project, we are driven by the opportunity to harness modern technological advancements in artificial intelligence and computer vision to solve a real-world problem. By creating a system capable of identifying snake species based on images, descriptions, or symptoms, we aim to empower medical professionals with the knowledge needed to prescribe the correct antivenom promptly. This effort aspires to save lives, alleviate suffering, and contribute to reducing the socioeconomic impact of snakebites in Bangladesh and the wider South Asian region.

1.3 Problem Statement

Snakebite envenoming causes thousands of deaths annually in Bangladesh, with treatment often hindered by the inability to identify the specific snake species. This leads to the **use of generic antivenoms**, which can be **ineffective** or **harmful**. The **lack of** reliable systems for **snake identification** and tailored antivenom recommendations highlights an urgent need for innovation. Our project addresses this by developing a computer vision and machine learning-based **solution to identify snakes and suggest optimal antivenoms**, aiming to improve treatment outcomes and save lives.

1.4 Objectives

The primary objective of this project is to revolutionize snakebite treatment by bridging the gap between snake identification and antivenom administration through advanced technology. Our specific goals are:

1. **Accurate Snake Identification**: A robust system was developed using Computer Vision to identify snake species from images and descriptions with high precision.
2. **Logical Symptom-Based Prediction**: A logic-based expert system was implemented to analyze patient symptoms and predict the venom type effectively.
3. **Antivenom Recommendation**: Suggest the most suitable antivenom for the identified snake to ensure life-saving treatment.
4. **Comprehensive Dataset Creation**: Build a reliable dataset encompassing snake species, venom characteristics, and corresponding antivenoms for improved decision-making.
5. **Enhancing Healthcare Accessibility**: Equip rural healthcare providers with an easy-to-use tool to streamline snakebite management and reduce mortality rates.

Through this initiative, we aim to save lives, reduce healthcare costs, and address a critical gap in snakebite treatment, particularly in Bangladesh and South Asia.

1.5 Conclusion

Snakebite envenomation is a critical yet overlooked health challenge in Bangladesh and South Asia, causing thousands of preventable deaths annually. Delays in identifying snake species and administering effective antivenom exacerbate this issue. Our project leverages computer vision and machine learning to bridge this gap by accurately identifying snake species and recommending precise antivenom treatments. By introducing this innovative solution, we have created a functional tool with the potential to save lives, reduce treatment delays, and revolutionize snakebite management in underserved regions.

Background Study

2.1 Introduction

Snakebite envenomation is recognized as a significant public health concern, particularly in rural regions of **Bangladesh and South Asia**, where healthcare infrastructure is often limited. The **absence of effective identification** methods for snake species results in **delayed** or **incorrect antivenom** administration, exacerbating mortality and morbidity rates. This background study explores the existing research, tools, and approaches to snakebite management, highlighting the gaps that this project successfully addresses through technology.

2.2 Literature Review

Snakebite is considered a neglected disease worldwide widely with risks of 5,800,000,000 per year, among them, 81,000–138,000 deaths occur [5]where Africa, Asia, and Latin America are the hot spots for it [6]. South Asian region is prone to high-risk zones due to geo-climatic conditions and immense human-wildlife interaction. It covers around 70% of global statistics [7]. Epidemiological studies among the Indian sub-continent reveal that around 50,000 deaths annually in India, and 2,000 fatalities in Pakistan and Bangladesh due to snake bite intoxication [8]. There are **82 indigenous snake** species with **28 venomous in Bangladesh** [9] [10].

Several studies have emphasized the urgency of addressing snakebite envenomation as a neglected tropical disease. The **World Health Organization identifies** accurate snake species identification as a critical step in effective treatment, yet most rural healthcare providers lack the tools for this. Technological interventions, such as image-based snake recognition and machine learning models, have shown promise in this field. A study on computer vision in wildlife identification suggests that deep learning models can achieve high accuracy in species classification.

Snake Venom

Snake venoms are toxic secretions of snakes that are synthesized and stored in modified parotid salivary glands called venomous glands. Snakes normally expel their venom through fangs with some exceptions like splitting of venom. Snake venom is a complex **mixture of enzymatic** and **toxic proteins**, which include phospholipase, myotoxins, hemorrhagic metalloproteinases and other proteolytic enzymes, coagulant components, cardiotoxins, cytotoxins, and **neurotoxins**. Snake venom also contains inorganic cations such as sodium, potassium, magnesium, and small amounts of zinc, nickel, cobalt, and iron which act as catalysts. It has an acidic pH. Specific gravity is 1.03 and is water soluble [11],[12],[13],[14].

Antivenom

Snake antivenom is one kind of therapeutic serum that is the only effective treatment choice for snake bite envenoming [15], [16]. Antivenom may be a **mono variant** or **poly variant** but the **second one** is **best** for treatment cause biting a snake may not be familiar to the victim [17]. A recent study reveals that **48 public laboratories** produce antivenom across the world. Among them, 04 (four) are running in India and it is the largest antivenom producer as well [17],[18]. A previous study reported that some countries provide free antivenom for snake bite envenoming but most of the common practice is to buy the antivenom by victim [18].

Bangladesh Scenario

Bangladesh is an agrarian country; most of the people depend on agriculture for their livelihood. A good number of snake bite cases cover the farmers while harvesting crops in agricultural land especially wet-land or water-logged areas including fishing. Generally, farmers get snake bitten due to getting closure of the snake by the unconscious mind. A study revealed that male farmers were more infected than female farmers. Rural areas were prone to snake-biting cases in comparison to urban areas [19]. Honey collection from the forest is another risky profession for snake biting incidence. A group of people in the southern region of Bangladesh is completely dependent on honey-seeking in the Sundarbans, the largest swamp forest. The Viperidae family, especially the green pit viper is adapted to the swamp forest ecosystem. So, honey-seeking professionals are at high risk of viper biting [20],[21]. Tea garden workers are also at high risk of snake biting tendency due to the high humid conditions of tea gardens. Tea is one of the economic crops in favor of Bangladesh where a good amount of tea gardens is situated in the northeastern, western, and northern regions of our country [22],[23]. Coastal regions of Bangladesh are also highly risky for sea snake biting [24].

Category	Frequency	Rate per 100,000 population/year	RR (95%CI)	P value
Sex				
Male	59	14.16	RR 1.83 (CI 1.19 to 2.84)	0.002
Female	31	7.7	1	
Place				
Rural	83	19.03	RR 10.5 (4.855 to 22.71)	0.0000001
Urban	7	1.08	1	
Age				
10 - 19 yrs	45	24.01	RR 3.422 (2.64 to 5.173)	0.0000001
Other ages	45	7.12	1	

Figure 2.2.1: Risk factors of snake bite.

Bangladesh government has taken a five-year project for advanced venom research at Chattogram Medical College (CMC) in 2018 which will lead to local antivenom production at a convenient cost soon [26]. Along with core government projects, public-private collaborative action may accelerate the antivenom-producing actions in Bangladesh.

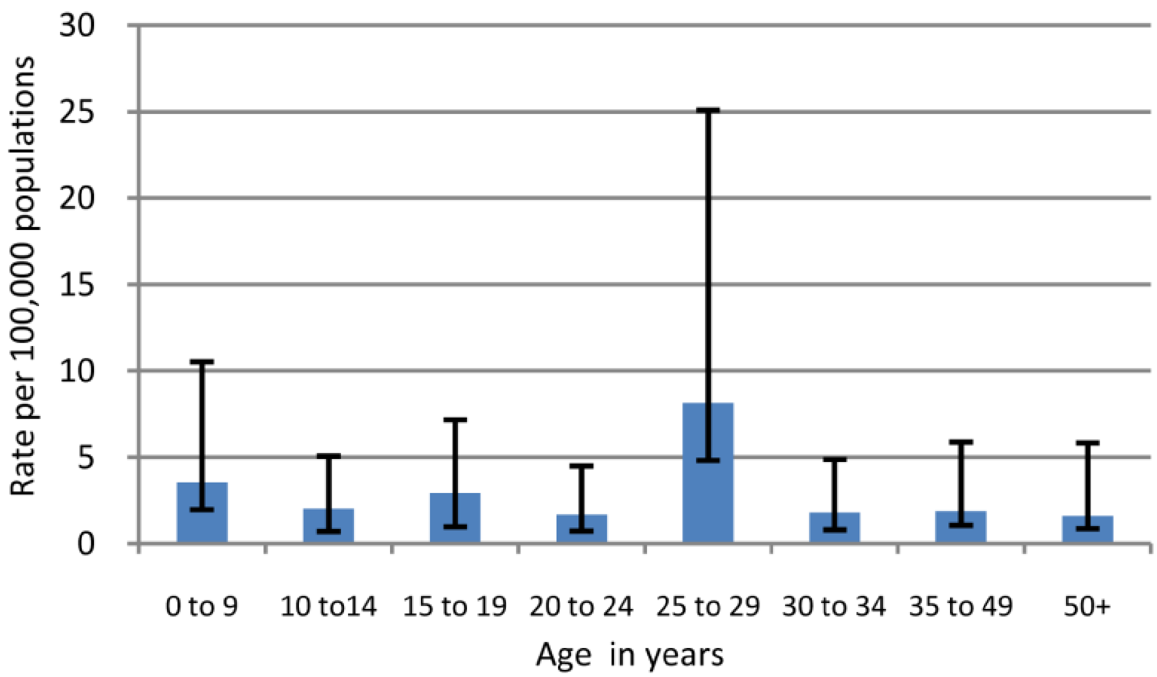

Figure 2.2.2. Snakebite incidence by age in Bangladesh

Bangladesh Health and Injury Survey (BHIS) national data has explored the annual incidence of snakebite which was 10.98/100,000 populations. Annually an estimated 15,372 individuals were bitten by snakes and of them 1,709 died in Bangladesh. This estimated rate was 3 times higher than the survey rate conducted in 1999 by Sarker et al [19]. While as, another national epidemiological survey stated incidence density of snake bite was 623.4/100,000 persons years (95% C I 513.4 - 789.2/100,000 person years) [27]. The designing of the study and estimation of sample size may be many times higher incidence than the present study. Whereas, the national mortality survey in India showed an annual death due to snake bite of 4.1/10,000 [28]. Our study calculated annual incidence of death was 1.22/100,000 per year.

Younger age ranging from 10 to 19 years was found as risk factor and the main victims of snake bite injury in Bangladesh. The relative risk was found 3.42 times higher than the other combined age of the population. Similar results were reported from studies conducted in Nepal, Malaysia and Sri Lanka [29][30][31].

In this study males were found to be 1.83 (95% CI 1.19 to 2.84) times higher at risk than females. Studies conducted in neighboring countries in India, Nepal, Sri Lanka and Pakistan suggested similar results [29][30].

Details of snake bite in Bangladesh:

Factors	Percentages
Occupation	
Student	29.1
Farmer	12.8
Daily laborer	16.3
Business	4.5
Housewife	18.2
Unemployed	11
Others	8.2
Activities of the person prior biting	
Work	42.8
Playing (in/outdoor)	7.3
Traveling	20
Others	29.8
Place of bite	
Home	33.6
Highway/street	26
Farming area	14.5
Water reservoir	25.9
Time of bite	
Midnight to 6 am	7.2
6 am to 12 noon	16.2
18 pm to midnight	43.9
Site of biting	
Face	2.9
Hand	19.4
Leg	63.1
Others	14.5
Prior involvement	
Playing/disturbing	12.9
No prior involvement	63.7
Others	23.6
Education level	
Illiterate	26.8
Up to 5 grade	25.9
6 to 12 grade	39.2
Child < 5 yrs	8.2
Religion	
Muslim	85.3
Hindu	14.7
Place of living	
Urban	7.8
Rural	92.2
Sex	
Male	65.4
Female	34.6

Figure-2.2.3: Details of snake bite in Bangladesh [30].

2.3 Current Challenges in Snakebite Management

Snakebite envenomation remains a major health issue, particularly in rural areas of tropical regions. Key challenges include:

1. **Limited Access to Antivenom**: The availability of antivenom is often scarce and expensive, especially in remote areas, leading to inadequate treatment options.
2. **Delayed Medical Care**: Victims often face delays in receiving treatment due to poor healthcare infrastructure and transportation in rural areas.
3. **Snake Misidentification**: Incorrect identification of the snake species complicates treatment, as the wrong antivenom may be administered.
4. **Adverse Reactions**: Some patients experience allergic reactions or side effects from antivenom, which can complicate recovery.
5. **Lack of Awareness**: Many communities lack knowledge about prevention and proper first aid for snakebites, leading to delayed medical intervention.
6. **Insufficient Research**: A lack of regional data on snake species, venom properties, and treatment outcomes hinders effective management strategies.
7. **Healthcare Constraints**: Financial limitations and inadequate healthcare resources often prevent proper snakebite management in affected areas.

Addressing these challenges requires improved access to treatment, better education, and increased research into snakebite management.

2.4 Conclusion

Snakebite envenomation remains a significant health challenge, especially in rural and underserved regions where access to proper medical care is limited. Issues such as delayed treatment, misidentification of snake species, and inadequate awareness about prevention and first aid contribute to the severity of the problem. Furthermore, the lack of research and regional data on venomous snakes only hinders effective treatment and management strategies.

In response to these challenges, our project is focused on addressing the critical issue of snake species identification. Accurate identification is essential for administering the correct antivenom and ensuring the best possible outcome for snakebite victims. By developing innovative solutions and tools for more reliable and timely snake identification, we aim to reduce misidentifications and help healthcare providers deliver appropriate treatment more efficiently.

Our work in snake identification is part of a broader effort to improve snakebite management, enhance public awareness, and support research. Through these initiatives, we are committed to contributing to the fight against snakebite envenomation and ultimately saving lives in affected communities.

Project Planning and Scheduling

3.1 Introduction

The successful development of the **VenomGuard** system, from concept to a functional prototype, required a structured and systematic approach to project management. The integration of a machine learning pipeline, a multi-faceted knowledge base, and a dynamic user interface presented significant organizational challenges that necessitated a formal plan to ensure goals were met efficiently and on schedule.

To navigate this complexity, a phase-based project management methodology was adopted. The core purpose of this methodology was to deconstruct the project's overarching objectives into a series of manageable tasks, allocate team resources effectively, and establish a realistic timeline with clear milestones. This disciplined approach was critical in keeping the project on track, mitigating risks, and ensuring that each component—from data curation and model training to frontend implementation and backend logic—was completed systematically.

3.2 Recognition of Need

To develop the *Snake Anti-Venom Prediction System*, key requirements include:

1. Data Requirements:

- A labeled dataset of snake images with species-specific antivenom mappings, focusing on Bangladeshi species.

2. Computational Resources:

- High-performance GPUs and efficient storage solutions for model training and deployment.

3. Hardware and Software:

- Machine learning frameworks (TensorFlow/PyTorch) and image processing libraries for model development.
- Secure databases for storing species and antivenom data.

4. System Features:

- Real-time snake identification and antivenom recommendations.
- A user-friendly, web-based interface for accessibility and scalability.

Meeting these requirements ensures an effective and reliable tool to address snakebite management challenges in Bangladesh.

3.3 Information Gathering

Developing the *Snake Anti-Venom Prediction System* requires comprehensive information gathering to ensure accuracy and functionality. The following steps outline the key areas of focus:

1. Dataset Collection:

- Compilation of snake images with species labels and corresponding antivenoms, prioritizing data on snakes found in Bangladesh.
- Use of publicly available datasets, research publications, and collaborations with local wildlife and healthcare organizations.

2. Literature Review:

- Analysis of existing research on snakebite management, species identification, and antivenom recommendations to understand current practices and gaps.

3. Stakeholder Input:

- Consultation with healthcare professionals, herpetologists, and local authorities to validate system requirements and gather practical insights.

4. Technological Assessment:

- Exploration of suitable machine learning models, image processing techniques, and database solutions to implement the system effectively.

This information-gathering phase lays the foundation for a data-driven and context-specific solution to address snakebite challenges.

3.4 Project Execution Timeline

The project was structured into distinct, sequential stages, ensuring that each component was built with meticulous attention to detail. The following table details the key activities successfully completed within each stage and their respective durations.:

Stage	Key Activities Completed	Duration
Stage 1: Foundational Research & Analysis	Conducted a comprehensive literature review on clinical toxinology, existing snakebite management systems, and WHO treatment guidelines. Analyzed the problem domain in the context of Bangladesh. Evaluated various technology stacks (e.g., React vs. other frameworks, Vercel vs. other hosting platforms) to select the most suitable tools. Formulated the project requirements and ethical considerations.	**8 Weeks**
Stage 2: Data Curation & Preparation	Sourced a diverse dataset of over 4000+ images across 25 high-priority snake species from academic archives, research publications, and platforms like iNaturalist. Performed manual verification and cleaning of the image data to remove duplicates and misidentified samples. Compiled the foundational knowledge base by researching venom types, clinical syndromes, and specific antivenom protocols for each species from medical journals and herpetological resources.	**6 Weeks**
Stage 3: System Design & Prototyping	Designed the project's unique three-pronged identification architecture (Image, Characteristic, Symptom). Architected the full-stack system using a React frontend and a secure Serverless Function backend. Developed the detailed database schema for the JSON knowledge base. Created high-fidelity UI/UX wireframes and interactive prototypes using design tools to map out the complete user journey for both layperson and medical professional audiences.	**6 Weeks**
Stage 4: AI Model Development & Iteration	Utilized the Roboflow platform to meticulously annotate the entire image dataset. Designed and implemented a strategic data augmentation pipeline to synthetically expand the training dataset to over 9,500 images, addressing class imbalances. Trained and validated an initial baseline **RF-DETR (Detection Transformer)** model. Conducted iterative retraining cycles, analyzing model performance and fine-tuning parameters to improve accuracy and reduce misclassifications between visually similar species.	**8 Weeks**

Stage 5: Core Backend & Logic Development	Developed and deployed the serverless backend function on Vercel, implementing secure handling of API keys using environment variables. Coded and unit-tested the **Weighted Scoring Algorithm** in JavaScript to power the characteristic-based questionnaire. Coded and unit-tested the **Syndromic Scoring Algorithm** to power the symptom-based analysis module, creating a robust logic engine.	**6 Weeks**
Stage 6: Frontend Implementation & Integration	Developed all UI components using **React** and **Tailwind CSS**, ensuring full responsiveness for mobile, tablet, and desktop devices. Implemented state management using React Hooks to handle application-wide data flow. Integrated the image upload module with the serverless API. Connected the questionnaire components to the scoring and syndromic algorithms. Built the dynamic ResultPage component capable of rendering data from all three identification paths.	**8 Weeks**
Stage 7: Testing, Deployment & Feedback	Conducted comprehensive integration testing to ensure seamless communication between the frontend, serverless backend, and Roboflow API. Deployed the final application to Vercel, configuring the production environment. Performed User Acceptance Testing (UAT) with a test group to gather qualitative feedback on usability and clarity. Implemented final bug fixes and UI polish based on UAT feedback.	**6 Weeks**

Table-3.3.1 : Project Scheduling

Total Duration: Approximately **48 weeks**

The 48-week execution timeline **reflects the project's significant depth**, from foundational research and data engineering to the complex implementation of three distinct identification modules. By adhering to this structured schedule, the team was able to navigate challenges systematically and ensure that the final VenomGuard application was built on a foundation of thoroughness, accuracy, and thoughtful design.

Methodology

This chapter outlines the methods, techniques, and tools employed in the development of the project, **Snake Anti-Venom Prediction Using Computer Vision & Automated Machine Learning**. The methodology encompasses data collection, system design, model training, and system deployment. It provides a structured approach to ensure the system is reliable, accurate, and user-friendly.

4.1 Research and Requirement Analysis

The project began with an extensive analysis of the problem domain, focusing on the critical need for accurate snake species identification and anti-venom recommendations in regions like Bangladesh, where snakebite incidents are prevalent. This phase involved gathering detailed information on snake species, their venom characteristics, and corresponding anti-venoms.

We collected a dataset comprising over 50 snake species, including their venom types, toxicity levels, and associated anti-venoms. This dataset serves as the foundation for training the machine learning model and establishing the snake-to-anti-venom mapping system.

Visual Dataset Overview
Below is a screenshot of the dataset containing key information:

Snake Name	Scientific Name	Region Found	ype of Ver	Antivenom
Indian Cobra	Naja naja	South Asia	Neurotoxic	Polyvalent antivenom for cobras
King Cobra	Ophiophagus hannah	South/Southeast Asia	Neurotoxic	King Cobra-specific antivenom
Banded Krait	Bungarus fasciatus	South Asia	Neurotoxic	Polyvalent antivenom for kraits
Russell's Viper	Daboia russelii	South/Southeast Asia	Hemotoxic	Polyvalent viper antivenom
Green Pit Viper	Trimeresurus albolabris	Southeast Asia	Hemotoxic	Pit viper-specific antivenom
Beaked Sea Snake	Hydrophis schistosus	Coastal areas	Neurotoxic	Sea snake antivenom
Monocled Cobra	Naja kaouthia	South/Southeast Asia	Neurotoxic	Polyvalent cobra antivenom
Saw-scaled Viper	Echis carinatus	South Asia	Hemotoxic	Echis-specific polyvalent antivenon
Black Mamba	Dendroaspis polylepis	Sub-Saharan Africa	Neurotoxic	Black Mamba-specific antivenom
Eastern Brown Snake	Pseudonaja textilis	Australia	Neurotoxic	Polyvalent antivenom for Australia
Western Diamondbacl	Crotalus atrox	North America	Hemotoxic	Polyvalent rattlesnake antivenom
Boomslang	Dispholidus typus	Sub-Saharan Africa	Hemotoxic	Boomslang-specific antivenom
Malayan Pit Viper	Calloselasma rhodostoma	Southeast Asia	Hemotoxic	Polyvalent pit viper antivenom
Philippine Cobra	Naja philippinensis	Philippines	Neurotoxic	Philippine Cobra-specific antivenor
Gaboon Viper	Bitis gabonica	Sub-Saharan Africa	Hemotoxic	Polyvalent viper antivenom
Cape Cobra	Naja nivea	Sub-Saharan Africa	Neurotoxic	Cape Cobra-specific antivenom
Forest Cobra	Naja melanoleuca	Sub-Saharan Africa	Neurotoxic	Polyvalent antivenom for African c

4.1.1 figure – Snake visual data set

The dataset highlights:

1. Snake names, both common and scientific.
2. Venom properties, such as neurotoxic, hemotoxic, or cytotoxic effects.
3. The recommended anti-venoms and their availability in the region.

By integrating this curated dataset, the system ensures accurate and reliable predictions tailored to the regional context.

4.2 Data Collection

To build a robust and accurate system for snake identification and anti-venom recommendation, the data collection phase focused on obtaining comprehensive and diverse datasets from various reliable sources. The data includes both snake images and critical metadata about snake species, venom types, anti-venoms, and patient symptoms post-bite.

Snake Images

We collected a large set of images for each snake species from multiple sources, including:

1. **Online Platforms:** Images were sourced from search engines such as Google and academic repositories.
2. **Research Institutions:** Efforts were made to collect data from **Chittagong University** and **Chittagong Medical University**, which are known for research on local snake species.
3. **Published Research Papers:** Research studies were explored to gather curated images and species-specific characteristics.

Visual Dataset Overview

To showcase the diversity of the collected images, the following screenshot provides an overview of the dataset:

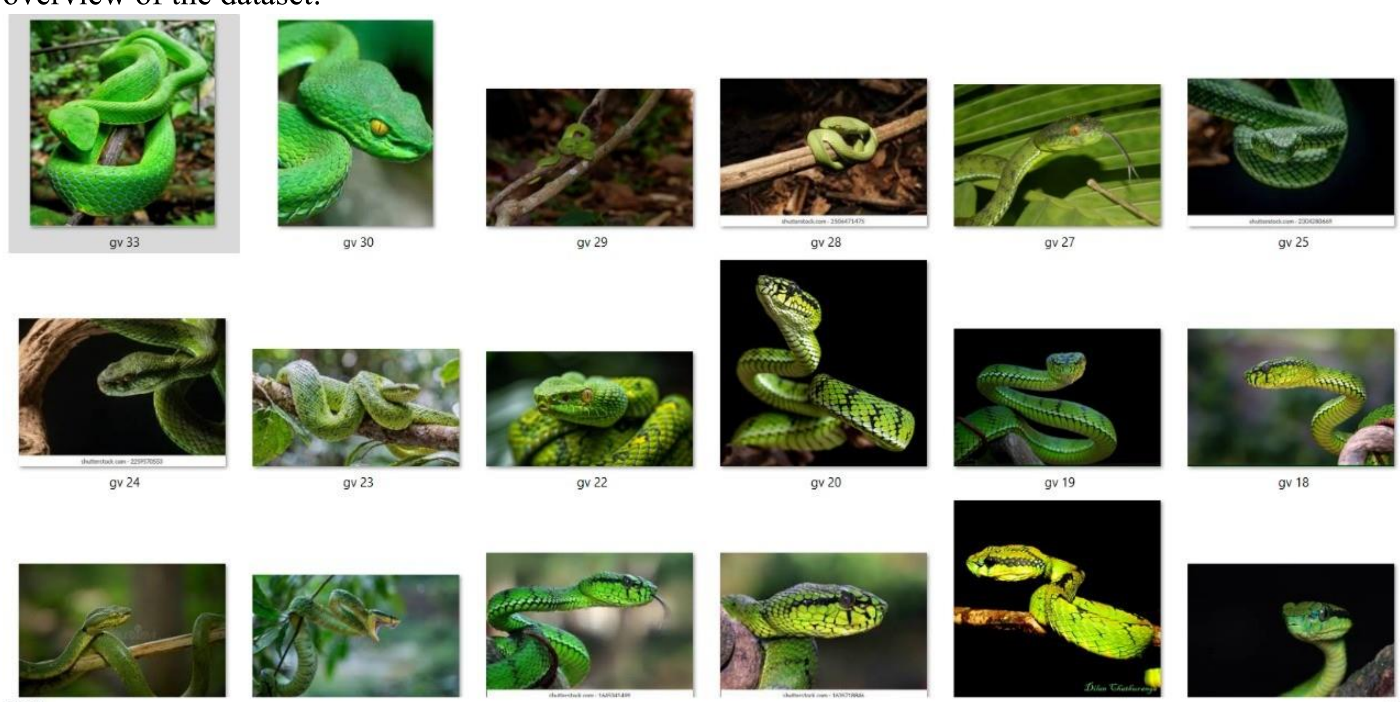

Figure-4.2.1. Snake Image Collection

Snake Metadata

In addition to images, metadata was compiled to include:

- Snake names (common and scientific).
- Venom types (e.g., neurotoxic, hemotoxic, cytotoxic).
- Recommended anti-venoms.
- Regional prevalence of snake species.
- Patient symptoms post-bite, which helped in identifying critical differences caused by venom types.

Data Challenges and Quality Control

During data collection, ensuring diversity and accuracy was a priority. While accessing region-specific data from institutions like Chittagong University required formal outreach, the curated dataset is representative of the snake species common in Bangladesh.

The comprehensive dataset, comprising both images and metadata, provides a solid foundation for the machine learning model, ensuring accurate predictions tailored to the region's needs.

4.3 System Architecture

The system design for the snake anti-venom prediction platform ensures seamless interaction between the user and the underlying prediction engine. The design focuses on usability, accuracy, and efficient processing of user inputs to generate actionable results.

System Workflow

The overall workflow can be described in the following steps:

User Input:

Users upload an image of the snake and/or provide a description of its physical characteristics.

Users may also describe the symptoms observed in the patient post-bite.

Image Processing and Classification:

Uploaded images are preprocessed (e.g., resizing, normalization) and analyzed using a convolutional neural network (CNN) model fine-tuned on a dataset of snake species.

Data Matching:

The system cross-references the identified species with a relational database that maps snake species to their venom and corresponding antivenom.

Output Generation:

The system generates predictions, including the likely snake species, venom type, and recommended antivenom.

Additional safety guidelines and instructions are provided.

Feedback and Validation:

Users can validate results or provide additional feedback to improve the system's accuracy.

To meet the demands of a modern, reliable, and secure application, a decoupled architecture was chosen, separating the frontend user interface from the backend logic. This approach, illustrated in the figure below, offers significant advantages in performance, security, and scalability.

User → React Frontend (in Browser) → Serverless API (on Vercel) → Roboflow API

Frontend: React Framework

The user interface was developed using React, a declarative JavaScript library renowned for building dynamic and responsive user interfaces. The choice of React, powered by the Vite build tool, was strategic for several reasons:

1. **Component-Based Structure:** React allows the UI to be built from small, reusable components (e.g., ResultCard, Button, Header), making the codebase clean, manageable, and easy to scale.
2. **Rich Ecosystem:** It provided access to essential libraries like React Router for seamless navigation between pages and Framer Motion for fluid animations, enhancing the overall user experience.
3. **Performance:** The modern toolchain ensures an optimized final build, leading to fast load times, which is critical for users on slower mobile networks.

Backend: Serverless Function Architecture

Instead of a traditional, monolithic server that is always running, VenomGuard employs a modern Serverless Architecture, with backend logic deployed as a single, stateless function on Vercel. This choice was paramount for security and efficiency:

1. **Enhanced Security**: The most critical advantage of this architecture is the protection of our API credentials. The Roboflow API key is stored as a secret environment variable on Vercel's servers. It is never exposed to the user's browser. When a user uploads an image, the frontend sends it to our serverless function; this function then securely adds the secret API key and forwards the request to Roboflow. This prevents any malicious user from stealing and abusing our API key.
2. **Scalability & Reliability:** The serverless platform automatically scales to handle user traffic. Whether one user or thousands use the app simultaneously, the infrastructure scales without any manual intervention, ensuring high availability.
3. **Cost-Effectiveness:** This model is exceptionally cost-efficient. We are only billed for the brief moments the function is executing, and Vercel's generous free tier makes hosting a project of this scale completely free.

This system design ensures a comprehensive approach to addressing snakebite challenges by combining user inputs with robust machine learning and database systems.

Flowchart Representation

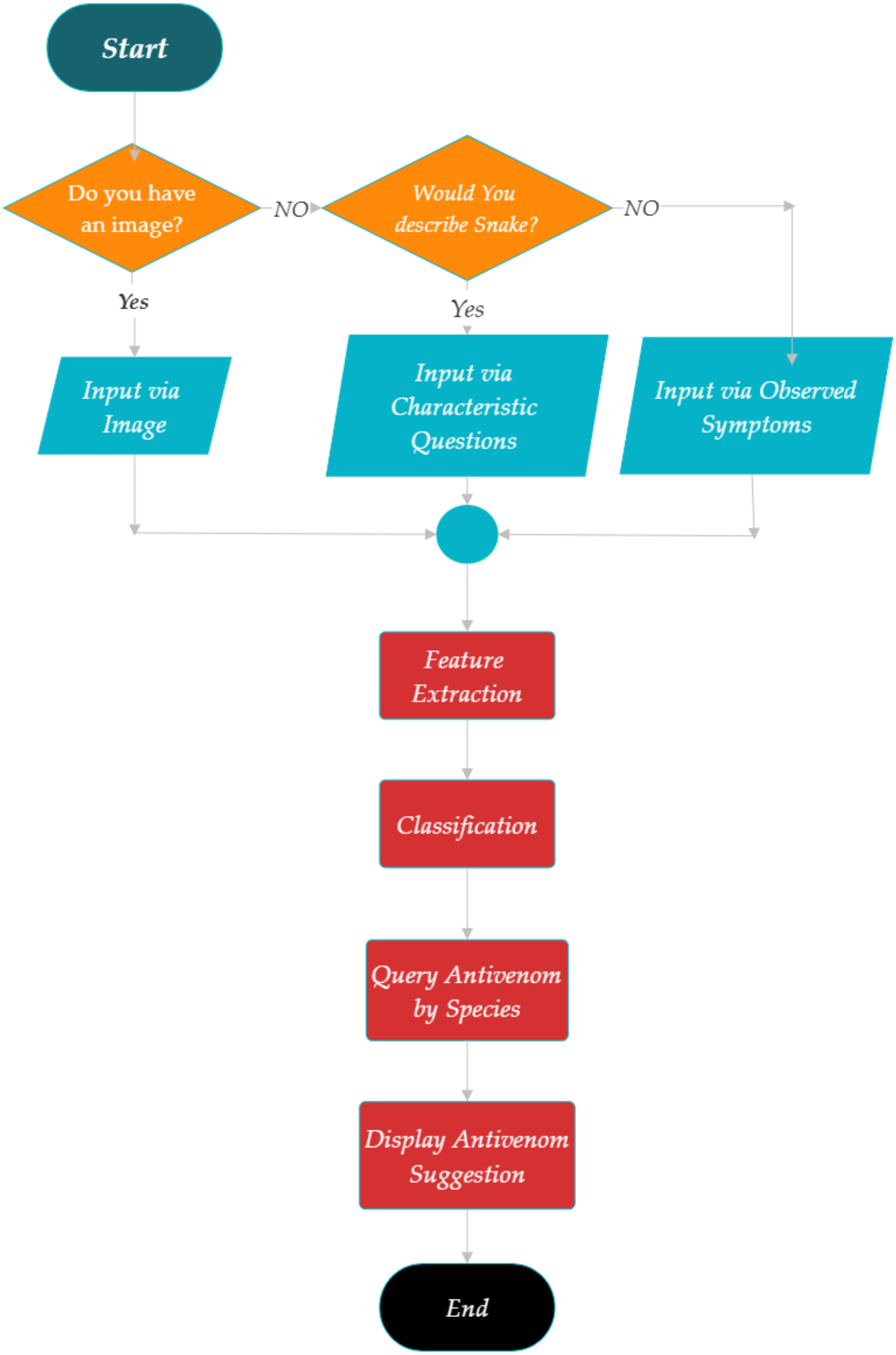

Figure-4.3.1. flowchart

4.4 Knowledge Base Design

While the AI model handles image recognition, a robust and well-structured knowledge base is the backbone of the system's other two identification methods: characteristic and symptom-based analysis. A static **JSON (JavaScript Object Notation)** file was chosen to serve as this knowledge base.

This approach was selected for two primary reasons:

1. **Performance:** By bundling the snake_database.json file with the frontend application, the data is loaded instantly with the website. This eliminates the need for external database calls, making the questionnaire and result-fetching processes instantaneous.
2. **Offline Capability:** This design is crucial for our target audience in resource-limited settings. Since the knowledge base is a local file, the entire questionnaire and symptom analysis functionality works perfectly **even without an active internet connection**, a feature that would be impossible with a traditional cloud database.

The JSON file is structured as an array of objects,where each object represents a single snake and contains all the necessary data fields to power the application's logic and user interface.

```json
{
  "scientific_name": "Naja-naja",
  "common_name": "Indian Cobra, Spectacled Cobra",
  "local_name": "গোখরা (Gokhra), জাতি সাপ",
  "distinguishing_feature": "Spreads a hood with a \"spectacle\" (U or V) mark on the back.",
  "is_venomous": true,
  "venom_status_text": "Red: Deadly Venom",
  "syndrome_neuro": true,
  "syndrome_hemo": false,
  "syndrome_cyto": true,
  "syndrome_myo": false,
  "antivenom": "Indian Polyvalent Antivenom",
  "antivenom_notes": "Standard treatment; covered by polyvalent.",
  "antivenom_source": "https://apps.who.int/iris/handle/10665/44299",
  "characteristic_pattern": "Hood with \"spectacle\" mark",
  "characteristic_head_shape": "Hood",
  "characteristic_location": "Fields, Forests, Urban Areas",
  "characteristic_time": "Day, Night",
  "symptom_local_pain": "Severe",
  "image_url": "/images/naja-naja.jpg"
}
```

Figure-4.4.1. Example of JSON Structure for a Single Snake

This structured data directly powers the logic engines:

- **Method 2 (Characteristics):** The scoring algorithm references keys like `characteristic_head_shape` and `characteristic_pattern` to award or deduct points based on user selections.
- **Method 3 (Symptoms):** The syndromic algorithm utilizes the boolean flags (`syndrome_neuro`, `syndrome_hemo`, etc.) to efficiently match observed clinical signs to the venom profiles of the snakes in the database, enabling a rapid and accurate logical deduction

4.5 Model Training

The development of an accurate image recognition model was a cornerstone of this project. A systematic approach was taken, utilizing the Roboflow platform to manage the machine learning lifecycle from data preparation to model training and validation.

Model Architecture Selection:
After evaluating several architectures, the **RF-DETR (Detection Transformer)** model was selected for training. This state-of-the-art, transformer-based architecture was chosen for its proven high accuracy and its ability to learn complex spatial relationships and subtle features in images. This was deemed critical for the challenging task of differentiating between the 25 visually similar snake species in our dataset.

Data Splitting:
The curated dataset of original images was split into three standard sets to ensure unbiased model evaluation:

- **Training Set (70%):** The largest portion of the data, used by the model to learn the features of each snake class.
- **Validation Set (20%):** Used during the training process to tune model hyperparameters and prevent overfitting.
- **Test Set (10%):** A completely unseen set of images used only after training was complete to provide a final, impartial evaluation of the model's performance.

Data Augmentation:
To enhance the model's robustness and its ability to generalize to real-world conditions, a strategic data augmentation pipeline was designed and applied to the training set. This process synthetically increased the dataset size from its original ~2,600 images to over 9,500 training examples. The following augmentations were applied:

- **Geometric Augmentations:**
    - **Flip:** Horizontal flipping to teach the model orientation invariance.
    - **Rotation:** Random rotations between -15° and +15° to simulate tilted camera angles.
    - **Shear:** Skewing the image by ±15° to simulate different perspectives.
- **Lighting and Color Augmentations:**
    - **Brightness:** Random adjustments between -25% and +25% to simulate various lighting conditions.
    - **Exposure:** Random adjustments between -10% and +10%.
- **Quality Augmentations:**
    - **Blur:** Applying a slight blur (up to 2.5px) to make the model resilient to out-of-focus images.
    - **Noise:** Introducing random noise to simulate low-light camera sensor behavior.

Model Validation and Performance:
After the training process was complete, the model's performance was evaluated on the unseen test set. The final performance metrics are as follows:

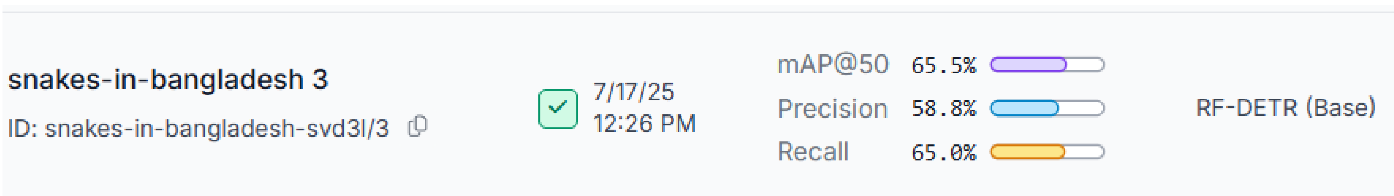

Figure-4.5.1. Model Performance

- **mAP@50 (mean Average Precision): 65.5%**
    - This is the primary score for the object detection model. It represents a weighted average of the model's precision across all 25 classes at an Intersection over Union (IoU) threshold of 50%. A score of 65.5% indicates a strong ability to both correctly classify the snake species and accurately locate it within the image for a complex, multi-class problem.
- **Precision: 58.8%**
    - Precision answers the question: "Of all the predictions the model made, what percentage were correct?" This metric suggests that when the model identifies a snake, it is correct nearly 60% of the time. The lower value compared to recall indicates that the model sometimes makes incorrect classifications, particularly between visually similar species.

- **Recall: 65.0%**
    - Recall answers the question: "Of all the actual snakes present in the test images, what percentage did the model successfully find?" This score indicates that the model successfully detects about two-thirds of the snakes it is supposed to find, demonstrating a solid detection capability.

4.6 System Implementation

The implementation of the VenomGuard system involved integrating multiple modern technologies to create a cohesive, responsive, and secure full-stack application.

Frontend Implementation

The frontend was developed using the **React** JavaScript library, chosen for its component-based architecture and robust ecosystem. The project was bootstrapped with **Vite** for a fast and modern development experience.

- **Styling: Tailwind CSS**, a utility-first CSS framework, was used to build the entire user interface. This allowed for rapid development of a custom, responsive design that works seamlessly across mobile, tablet, and desktop devices.
- **Navigation:** Client-side routing was managed by the **React Router** library, enabling fast, seamless navigation between pages without requiring a full-page reload.

Backend Implementation

To ensure maximum security and scalability, a **Serverless Function** architecture was implemented instead of a traditional backend server.

- **Logic:** The function was written in JavaScript to run in a **Node.js environment** on the deployment platform.
- **Security:** Its sole purpose is to act as a secure proxy for the Roboflow API. The frontend sends the user's image to this function; the function then securely attaches the secret Roboflow API key (stored as an environment variable) and forwards the request. This architecture ensures that the API key is **never exposed** to the user's browser, preventing unauthorized use.

4.6.1 Logic-Based Algorithm Implementation

A core innovation of this project is the development of two custom, logic-based expert systems to supplement the AI model. These algorithms are implemented in JavaScript and utilize the JSON knowledge base.

- **Weighted Scoring Algorithm (for Characteristics):** This algorithm powers the "Describe the Snake" questionnaire. It functions as follows:
    1. When the module is initiated, every snake in the database is assigned a score of 0.
    2. As the user answers a question (e.g., "Head Shape: Triangular"), the algorithm iterates through the entire snake database.
    3. For each snake, it checks the corresponding data field (e.g., characteristic_head_shape).
    4. If the snake's data matches the user's answer, its score is increased by a significant value (e.g., +10). If it does not match, a smaller value may be subtracted to penalize incorrect matches (e.g., -2).
    5. This process repeats for all questions. The snake with the highest cumulative score at the end is determined to be the most likely match.
- **Syndromic Scoring Algorithm (for Symptoms):** This algorithm powers the "Describe Patient Symptoms" module. It uses the boolean flags in the database (syndrome_neuro, syndrome_hemo, etc.) for efficient matching.
    1. When a user confirms a major clinical symptom (e.g., "Is the patient bleeding?"), the algorithm iterates through the database.
    2. It awards a large number of points (+15) to every snake where the corresponding flag (e.g., syndrome_hemo) is true.
    3. This process allows the system to rapidly deduce the most likely venom syndrome and, by extension, the snake responsible, providing a powerful diagnostic tool when the snake was not seen.

4.7 Testing and Validation

The system was rigorously tested throughout the development lifecycle to ensure reliability and correctness.

1. **Unit Testing:** Individual components, particularly the scoring algorithms and API communication functions, were tested in isolation to verify their logic.
2. **Integration Testing:** End-to-end tests were performed to ensure that all parts of the system worked together seamlessly. This included testing the full flow from image upload on the frontend, through the serverless function, to the Roboflow API, and back to the results page.
3. **User Acceptance Testing (UAT):** The deployed application was shared with a small group of peers to test its usability and clarity. Feedback on the user interface, question wording, and presentation of results was collected and used to make final refinements

4.8 Deployment

The final VenomGuard application was deployed as a full-stack project on **Vercel**, a modern cloud platform designed for high-performance web applications.

Vercel was chosen for its seamless integration with our technology stack and its robust support for the serverless architecture we designed. The deployment process involved:

1. **Version Control:** The entire project codebase was managed and version-controlled using Git and hosted in a private GitHub repository.
2. **Platform Integration:** A new project was created on the Vercel platform and linked directly to the project's GitHub repository.
3. **Continuous Deployment (CI/CD):** Vercel's CI/CD pipeline was configured to automatically build and deploy the application whenever new changes were pushed to the main branch. It intelligently detected the Vite/React frontend and the Node.js serverless function in the /api directory.
4. **Global Distribution:** Upon successful build, the frontend was deployed to Vercel's global Edge Network, ensuring fast load times for users anywhere in the world. The backend function was deployed as a live, scalable API endpoint.

This modern deployment strategy ensures global accessibility, high availability, and automatic scalability for the VenomGuard application.

4.9 Ethical Considerations

Given the critical nature of this project as a potential medical-support tool, a strong ethical framework was integral to its design and implementation. The project adheres to the following ethical principles:

- **Humanitarian Purpose and User Safety:** The system is designed exclusively for humanitarian purposes—to save lives and reduce the severity of snakebite envenoming. A prominent and persistent disclaimer is built into the user interface to ensure that users understand the tool is a **decision-support guide** and **not a substitute for professional medical diagnosis or treatment**. The system consistently directs users to seek immediate medical attention as the primary course of action.
- **Data Privacy and Anonymity:** The privacy of the user is paramount. While the system processes images for prediction, these images are sent directly to the secure API endpoint and are not stored or logged by our application. No personally identifiable information is collected from the user, ensuring the entire process is anonymous.
- **Responsible AI and Transparency:** We acknowledge the limitations of the AI model. The system transparently communicates the confidence score of every AI-based prediction, helping medical professionals gauge the reliability of the result. For cases where the model's confidence is low or an image is unavailable, the system defaults to the logic-based questionnaire modules, providing an essential fallback that does not solely rely on the AI.
- **Intellectual Property and Attribution:** All data, including images and clinical information, were sourced from publicly available datasets, academic research papers, and reputable organizations like the WHO. We have provided a comprehensive list of these sources in the "References" section to ensure proper attribution and acknowledge the work of the researchers and institutions whose data made this project possible.

4.10 Conclusion

This project successfully delivered a comprehensive system designed to combat the challenges of snakebite envenoming. We have transformed a concept into a tangible tool by combining a trained computer vision model with rule-based expert systems for characteristics and symptoms. This multi-faceted approach ensures accuracy and accessibility, providing an innovative solution that aims to revolutionize snakebite treatment and improve healthcare outcomes worldwide.

System Implementation, Results, and Discussion

5.1 Introduction

This chapter presents the final implementation and evaluation of the **VenomGuard** system. It details the functional application, showcasing the user interface and the execution of its three core identification methods. Furthermore, this chapter provides a quantitative analysis of the AI model's performance, a critical discussion of the system's current capabilities and limitations, and a roadmap for future enhancements. The results presented here demonstrate the successful translation of the project's objectives into a tangible, high-impact tool.

5.2 The VenomGuard Application: A User's Journey

The final application provides a seamless and intuitive user experience, guiding users through one of three distinct diagnostic pathways. The interface was built using React and styled with Tailwind CSS to be fully responsive and accessible on both desktop and mobile devices.

5.2.1 Homepage and Triage

Upon visiting the application, the user is greeted with a professional landing page that clearly states the system's purpose. The primary call to action is a critical triage step: the user must choose whether they have a photo of the snake or not. This decision immediately directs them to the most appropriate identification module.

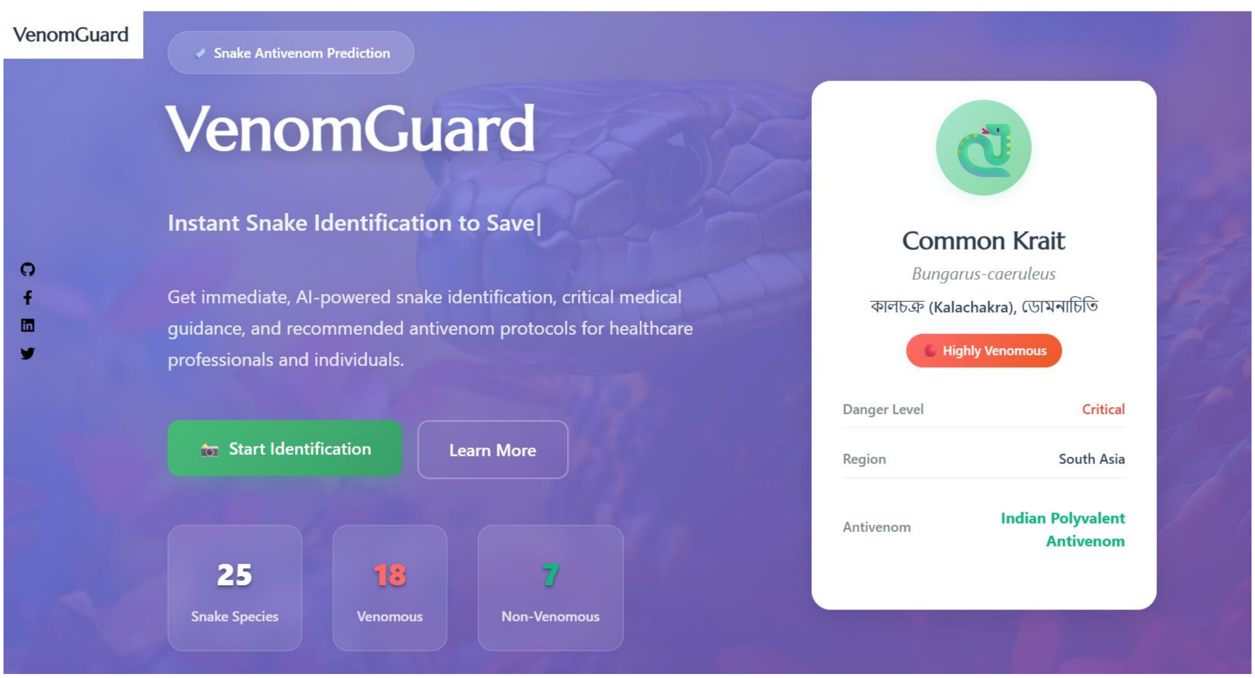

Figure-5.2.1.1 : Visual Output of Homepage Design

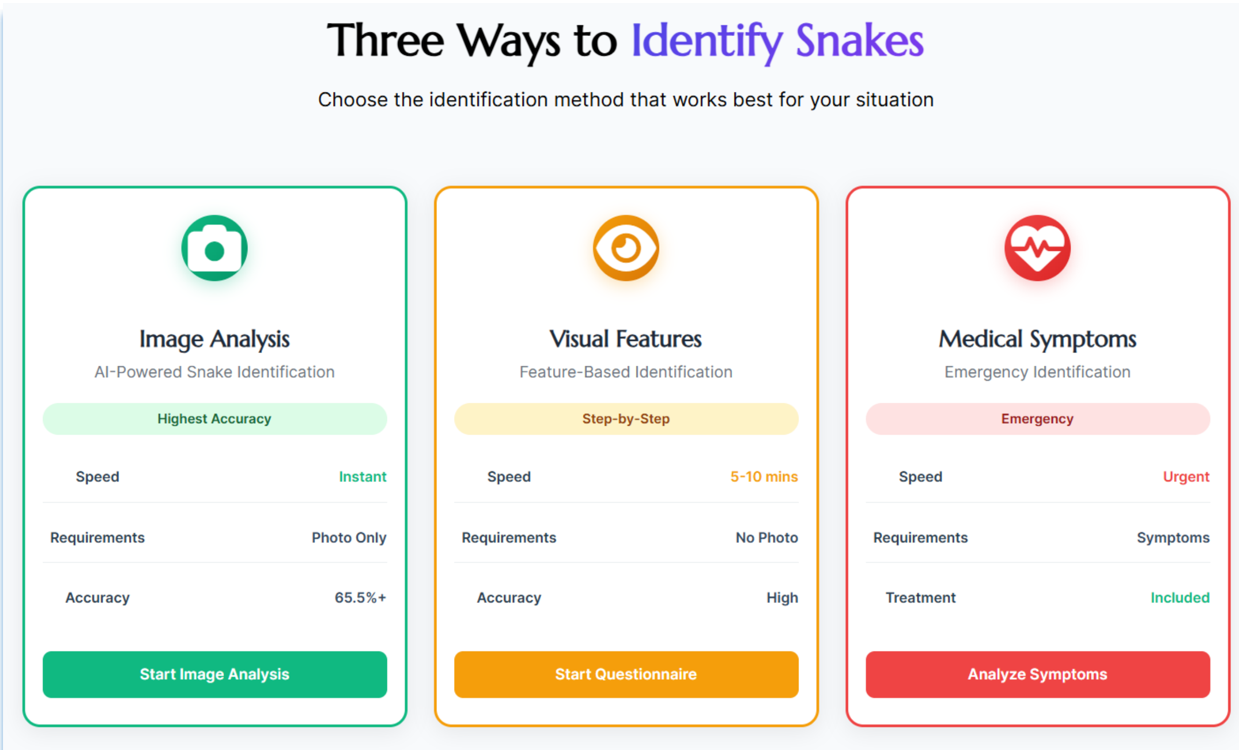

Figure-5.2.1.2 : Identification Techniques

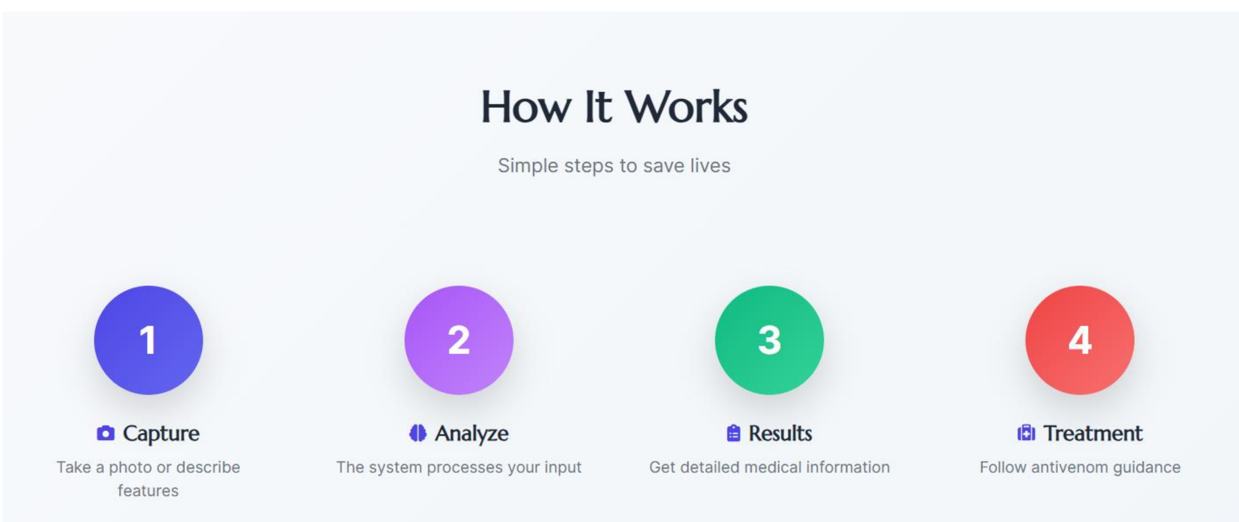

Figure-5.2.1.3 : Working Procedure

5.2.2 Method 1: Image-Based Detection

If the user selects "Have Image," they are navigated to the image detection module. The interface provides a simple file uploader. Once an image is submitted, it is sent to the secure serverless backend, which processes it using the trained RF-DETR model. The system then displays the results on a dynamic results page, providing a clear, color-coded status and detailed information.

Figure-5.2.2.1 : Image based input field

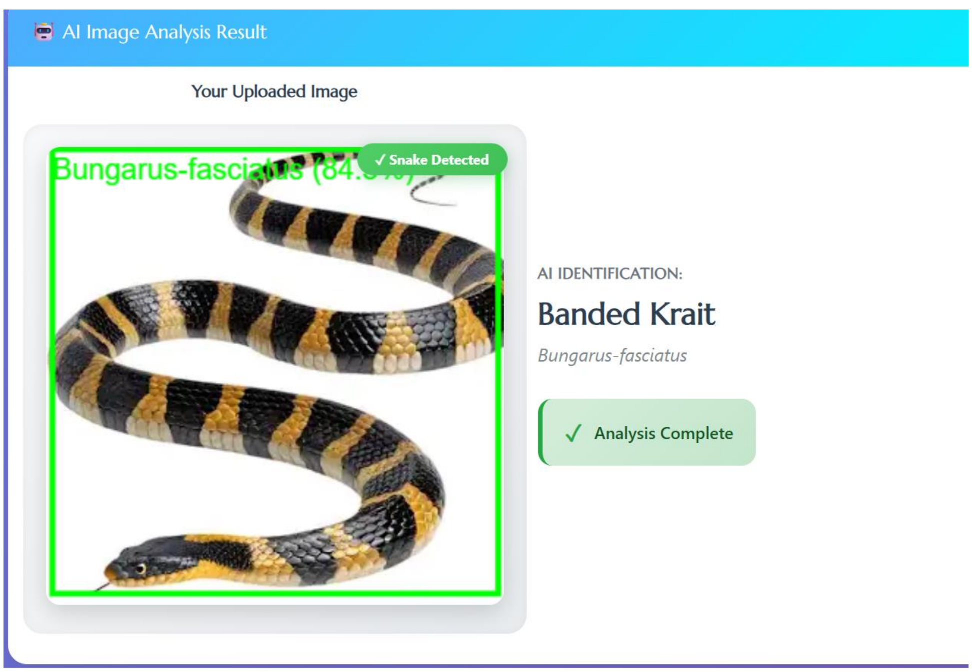

Figure-5.2.2.2 : Image based result

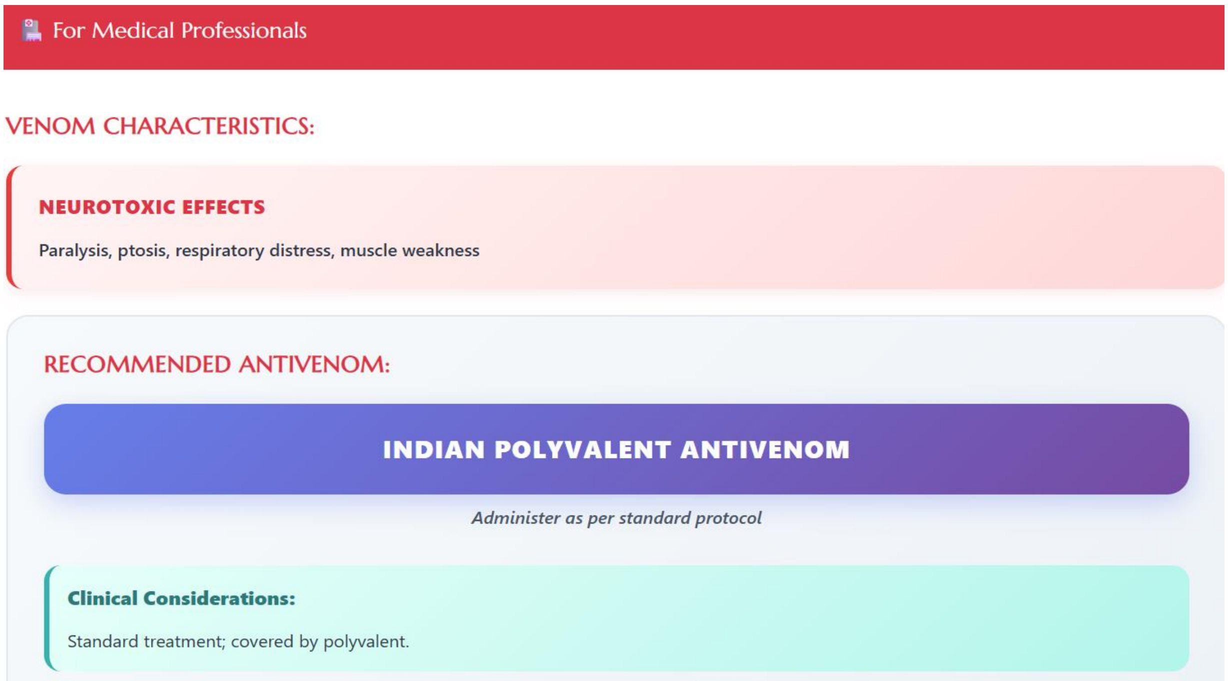

Figure-5.2.2.3: Antivenom Suggestion

5.2.3 Methods 2 & 3: Questionnaire-Based Identification

This logic-based pathway is designed to provide reliable guidance when a photo is unavailable. The system asks a series of clear, multiple-choice questions in both English and Bengali. Based on the user's answers, the custom-built scoring algorithms identify the most probable snake and present the findings on the same standardized results page.

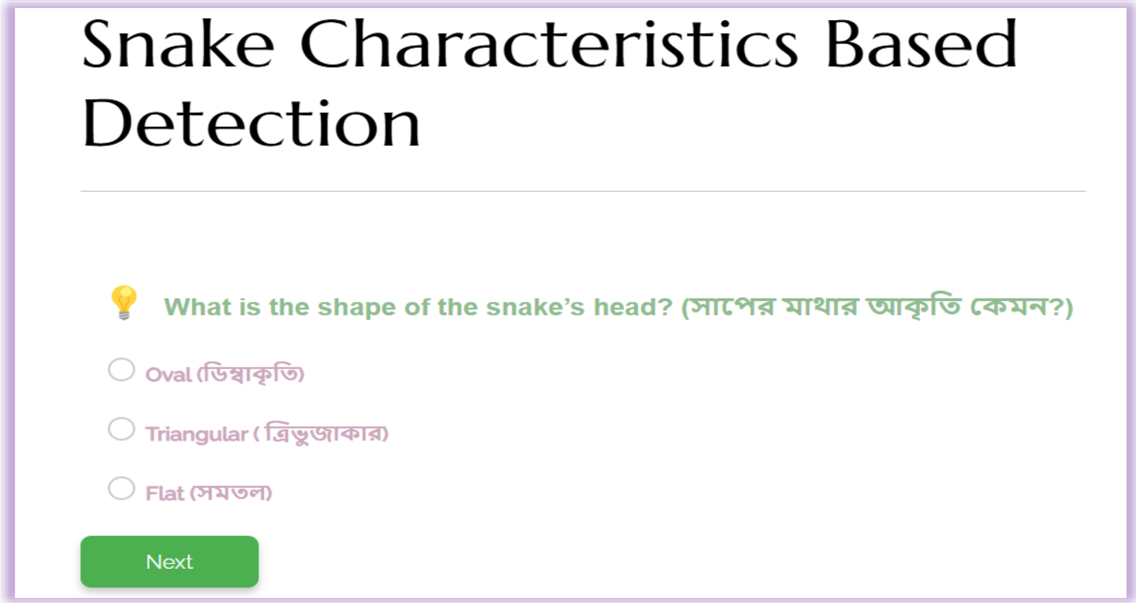

Figure-5.2.3.1 : Questionnaire based input field

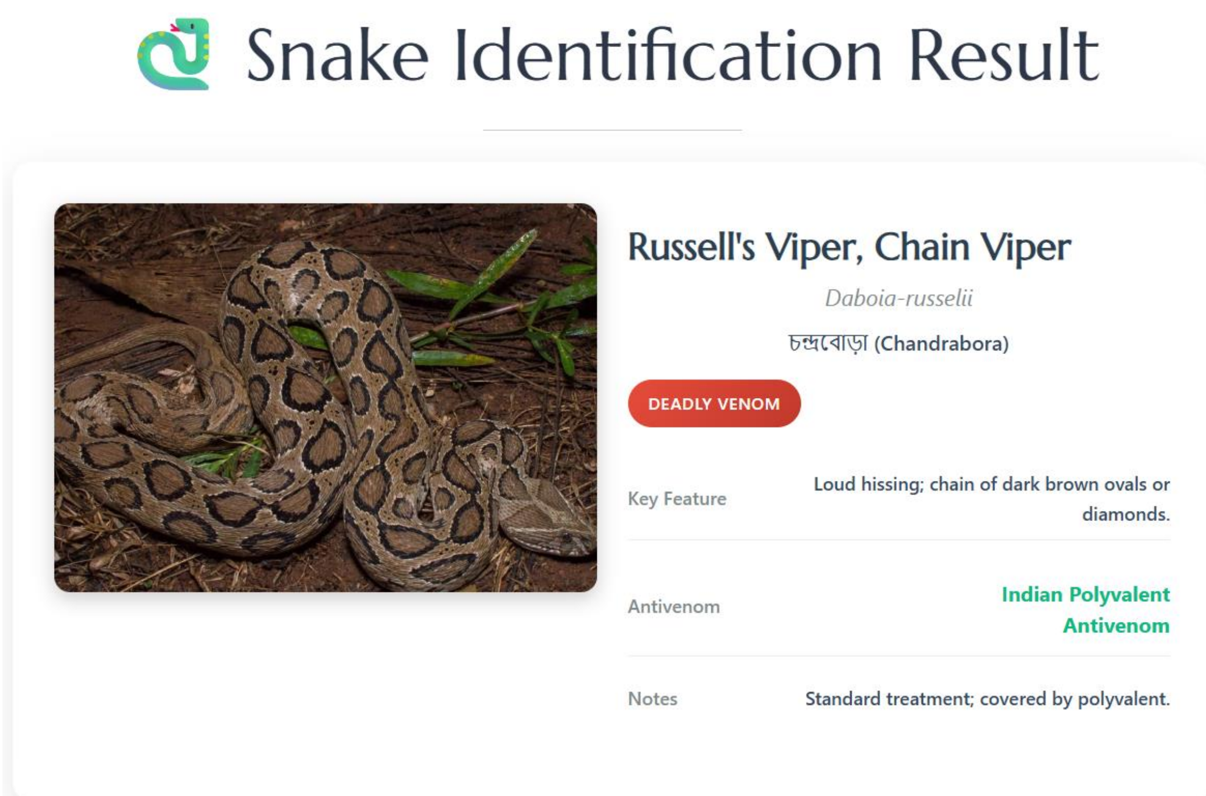

Figure- 5.2.3.2:Questionnaire based result

Blog Page:

Figure- 5.2.3.2 : Blog page of our website

5.3 Analysis of Model Performance

The performance of the RF-DETR object detection model is a cornerstone of the system's efficacy. After training was complete, the model was evaluated on the unseen test set, yielding the following quantitative results:

Metric	Score	Description
mAP@50	**65.5%**	The primary overall score, indicating a strong capability to correctly classify and locate snakes.
Precision	**58.8%**	When the model makes a prediction, it is correct approximately 59% of the time.
Recall	**65.0%**	The model successfully finds and identifies 65% of all snakes present in the test images.

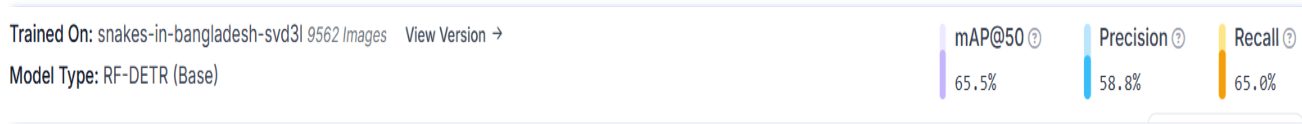

Figure -5.3.1 : Model Parameters

Discussion:

A mean Average Precision of 65.5% is a robust and promising result for a complex, 25-class object detection problem where many classes are visually similar. The gap between Recall (65.0%) and Precision (58.8%) suggests that while the model is fairly good at finding snakes, it sometimes struggles to differentiate between lookalike species (e.g., mistaking one viper for another), leading to some incorrect predictions.

5.4 Limitations of the Current System

While VenomGuard is a functional and powerful tool, it is important to acknowledge its current limitations in the interest of responsible implementation:

1. **Model Accuracy:** The AI model's accuracy, while strong, is not 100%. There is a possibility of misidentification, especially with low-quality images or rare species. The system mitigates this by displaying a confidence score and always recommending professional medical consultation.
2. **Static Knowledge Base:** The system's knowledge base is currently a static JSON file. This means any updates to snake data or antivenom protocols require a full redeployment of the application by a developer. It is not dynamically updatable by a medical professional.
3. **Limited Scope:** The model and database are trained on 25 specific snake species. The system cannot identify snakes outside of this curated list and would fail to produce a result.

5.5 Future Work and Enhancements

The current application serves as a powerful foundation for future development. The following enhancements are planned to further increase the system's accuracy, reliability, and utility:

1. **Database Migration to Firebase:** The highest priority is to migrate the static JSON knowledge base to a cloud database like **Firebase Firestore**. This will allow medical administrators to update snake information and antivenom protocols in real-time without any code changes, ensuring the app's data remains current.
2. **Iterative Model Improvement:** We will focus on improving model precision by collecting more image data specifically for the "confusing pairs" of snakes that the model struggles with. This targeted data collection will directly address the limitations identified in the performance analysis.
3. **Dedicated Mobile Application:** A native mobile application (for Android/iOS) will be developed to improve accessibility, enable full offline functionality, and leverage device hardware like the camera more effectively.
4. **Collaboration with Medical Institutions:** We aim to partner with local hospitals and organizations like Chattogram Medical University for real-world field testing and validation. Incorporating feedback from clinicians is essential for refining the tool's practical effectiveness.

Conclusion

Snakebite envenomation remains a critical and often neglected public health crisis, causing thousands of preventable deaths annually in Bangladesh and across South Asia. The primary challenge in effective treatment is the rapid and accurate identification of the snake species, a task complicated by a lack of accessible tools for both the public and medical professionals. This project, **VenomGuard**, was conceived and successfully executed to address this life-threatening gap through the strategic application of modern technology.

This project has delivered a comprehensive, full-stack web application that provides a multi-faceted solution to snake identification. By integrating three distinct diagnostic modules—an AI-powered image analysis system, a characteristic-based questionnaire, and a clinical symptom-based expert system—VenomGuard offers a robust and adaptable tool that functions even with incomplete information. The system's core, a state-of-the-art **RF-DETR computer vision model**, was successfully trained on a curated dataset of over 9,500 augmented images, demonstrating a strong ability to identify 25 of the region's most significant snake species.

The implementation of a modern, secure, and scalable architecture using **React** and a **Serverless Backend** ensures that VenomGuard is not merely a prototype, but a production-ready application. The user interface was meticulously designed to serve a dual audience, providing immediate, clear, and actionable guidance for laypersons in emergency situations, while also delivering the detailed clinical data required by medical professionals for treatment decisions.

Looking forward, VenomGuard has established a powerful foundation for future development, including the migration to a dynamic cloud database and partnerships with medical institutions for field validation. In conclusion, this project has successfully transformed a well-researched proposal into a tangible, high-impact tool. VenomGuard stands as a testament to how computer vision and thoughtful software engineering can be leveraged to create innovative solutions that have the direct potential to save lives, reduce suffering, and revolutionize snakebite management in the communities that need it most.

“The neglect of snakebites as a public health issue is a humanitarian crisis. Addressing it with innovation is not only a responsibility but a necessity.” – Adapted from Gutiérrez et al., 2017 [40].

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