BarristerBot, Your AI base Legal Advisor

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Department of Information Technology
University of Haripur
September, 2024

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BACHELOR OF SCIENCE

IN

COMPUTER SCIENCE

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CERTIFICATE

A THESIS SUBMITTED IN THE PARTIAL FULFILMENT OF THE
REQUIRMENTS FOR THE DEGREE OF BACHELORS
IN COMPUTER SCIENCE

We accept this dissertation as conforming to the required standards

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September, 2024

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Dedicated to

Our respectable parents and teachers.

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All praise to Allah, the most beneficent, the most merciful. His kindness and blessings allowed me to accomplish this task. I would like to appreciate the help of my supervisor Dr. Mukhtaj Khan whose suggestions, encouragement and guidance is a real source of inspirations for me throughout the entire course of my study. I would also like to thank the PhD students of my department for helping me in any way they could. Furthermore, I would like to thank my parents and friends who extended their great support during data collection. Thanks to everybody who supported me in one or the other way to convert my thesis to successful thesis

Abstract

Access to legal information is fundamental for protecting citizens' rights and ensuring justice in any society. However, in Pakistan, citizens face significant barriers in accessing legal assistance, including prohibitively high consultation fees, complex legal jargon, limited access to legal resources, and a time-consuming process of finding relevant case precedents. Many individuals, especially from lower-income backgrounds, often navigate legal challenges without proper guidance due to these constraints.

This thesis presents BarristerBot, a GenAI-powered legal advisory chatbot designed to address these challenges. The system leverages Retrieval-Augmented Generation (RAG) technology to provide instant, accurate legal guidance in simple language while maintaining cost-effectiveness. Users can interact with BarristerBot through an intuitive interface to receive relevant case law information and legal advice, and procedural guidance 24/7. The platform features real-time case law retrieval, personalized responses based on user expertise levels, and supports both text and speech interactions to ensure accessibility for all users.

This solution represents a significant step toward democratizing legal access in Pakistan, potentially transforming how citizens interact with the legal system while making justice more accessible and affordable for all.

Keywords: Generative AI, Large Language Models, RAG (Retrieval-Augmented Generation)

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Chapter 1

Introduction

1.1 Overview

Access to legal knowledge and assistance is fundamental to upholding justice and protecting citizens' rights in any democratic society. Legal awareness enables individuals to understand their rights, obligations, and available remedies under the law, while proper legal guidance ensures they can effectively navigate complex legal procedures. In an increasingly complex legal landscape, the availability of reliable legal information and assistance becomes crucial for ensuring equal access to justice.

According to the World Justice Project's Rule of Law Index 2023, Pakistan ranks 130th out of 142 countries in terms of access to civil justice. The Pakistan Bar Council reports an alarming ratio of one lawyer per 3,500 citizens, significantly below the recommended international standard. Furthermore, the Law and Justice Commission of Pakistan's 2023 report indicates a backlog of over 2.2 million cases across various courts, highlighting the overwhelming strain on the legal system [3].

Table 1: Pakistan's WJP Rule of Law Index rankings [1]

FACTOR	GLOBAL RANK	REGIONAL RANK*	INCOME RANK**
Constraints on Government Powers	95/142	4/6	17/37
Absence of Corruption	123/142	5/6	28/37
Open Government	105/142	4/6	20/37
Fundamental Rights	125/142	4/6	28/37
Order and Security	141/142	5/6	37/37
Regulatory Enforcement	128/142	5/6	31/37
Civil Justice	129/142	4/6	30/37
Criminal Justice	99/142	4/6	19/37

These statistics translate into real challenges for Pakistani citizens. High consultation fees make professional legal advice unaffordable for approximately 68% of the population, as reported by the Pakistan Institute of Development Economics (PIDE) [2]. Citizens often face intimidating legal jargon, complex procedural requirements, and lengthy waiting times for legal consultations. This lack of accessible legal guidance frequently leads to missed deadlines, procedural errors, and in many cases, the complete abandonment of legitimate legal claims.

Several initiatives have attempted to address these challenges in Pakistan. The Punjab Judiciary's online case tracking system [4] and the Federal Ombudsman's complaint portal represent government efforts to digitize legal services. Private sector solutions like "Vakeel Online" and "Legal Point Pakistan" have emerged to provide digital legal assistance. However, these platforms have significant limitations: they often require substantial legal literacy, lack real-time interaction capabilities, operate with outdated databases, and frequently provide generic information without context-specific guidance.

BarristerBot addresses these limitations through innovative technological solutions. Unlike existing platforms, it employs Retrieval-Augmented Generation (RAG) technology to provide accurate, contextual legal guidance in real-time. The system's vector database implementation through Pinecone/FAISS efficiently manages over 50,000 Pakistani legal cases and statutes, ensuring responses are based on current and relevant legal precedents. Additionally, the platform's bilingual support (English and Urdu) and text-to-speech capabilities make it accessible to a broader audience.

The technical architecture of BarristerBot combines several cutting-edge technologies. Built on Next.js, the platform offers a responsive and intuitive user interface. The LangChain framework powers the RAG pipeline, enabling natural language understanding and generation. The system maintains strict privacy standards through PII masking and ensures 24/7 availability through both cloud and local deployment options. With an average response time of under 3 seconds, BarristerBot provides immediate, accurate legal guidance while maintaining cost-effectiveness.

This innovative approach to legal assistance represents a significant step toward democratizing legal access in Pakistan. By combining advanced technology with user-

centric design, BarristerBot has the potential to transform how citizens interact with the legal system. As the legal tech market in Pakistan projects 300% growth by 2026, solutions like BarristerBot become increasingly crucial in bridging the gap between citizens and their legal rights, making justice more accessible and affordable for all.

1.2 Problem Statement

Access to legal services in Pakistan presents a significant challenge for the majority of its population. High consultation fees make professional legal guidance unaffordable for more than two-thirds of citizens. The problem extends beyond financial constraints to include multiple barriers: complex legal terminology that most citizens struggle to understand, time-consuming processes to find relevant legal information, overwhelming backlog of cases in courts, and limited availability of legal professionals. Existing digital solutions have attempted to address these issues but fall short due to outdated information, lack of real-time assistance, and inability to provide context-specific guidance in simple language. The language barrier further compounds these challenges, as most legal resources are available only in English, despite Urdu being the primary language for many citizens. To address these multifaceted challenges, we have developed BarristerBot, an AI-powered legal advisory system that aims to provide accessible, affordable, and accurate legal guidance to Pakistani citizens while overcoming the limitations of existing solutions.

1.3 Project Objectives

The main objective of our project is to develop a chatbot that helps people solve legal problems by providing affordable, accessible, and reliable guidance anytime they need it. Here are the key objectives we're aiming to achieve:

- Design a user-friendly, multilingual interface to ensure accessibility for diverse users.
- Support both text and speech input for enhanced user interaction.
- Implement LLM and RAG technology for accurate legal assistance.
- Build a dynamic knowledge base with real-time legal updates.
- Ensure privacy with PII masking and data security protocols.

- Ensure 24/7 availability through cloud and local LLM support.
- Tailor responses to user profiles for personalized legal support.
- Provide cost-effective legal support, accessible to all.

1.4 Project Scope

This project encompasses the development of BarristerBot, an AI-powered legal advisory system specifically designed for the Pakistani legal context. The scope includes the creation of a comprehensive RAG (Retrieval-Augmented Generation) pipeline using LangChain framework, implementation of vector databases for efficient storage and retrieval of legal documents, and development of a user-friendly web interface using Next.js. The system will offer legal guidance on various aspects of Pakistani law, including civil, criminal, and constitutional matters, through both English and Urdu language support.

BarristerBot will offer real-time query responses, case law references, and procedural guidance while maintaining user privacy through PII masking. The project includes the development of both cloud-based and local deployment options to ensure wider accessibility. However, it's important to note that BarristerBot is designed to serve as an advisory tool and not a replacement for professional legal counsel. The system will not engage in the direct filing of legal documents, representation in court proceedings, or provision of binding legal opinions. The focus remains on making legal information more accessible and understandable for Pakistani citizens while maintaining ethical and professional boundaries.

Chapter 2

Existing Systems

Introduction

As digital transformation accelerates across industries, the legal sector has witnessed the emergence of various AI-powered solutions aimed at democratizing legal access. Current technological advancements, particularly in natural language processing and retrieval-augmented generation, have enabled the development of sophisticated legal advisory systems. While existing solutions have made progress in areas such as document automation, case law search, and basic legal guidance, there remains a significant opportunity for more comprehensive, user-friendly, and context-aware systems. Current implementations range from simple chatbots to document management systems and case prediction tools, each addressing specific aspects of legal accessibility challenges.

2.1 Existing Systems

Several notable attempts have been made to leverage technology in improving legal access. These systems vary in their approach, complexity, and effectiveness in addressing user needs. The following analysis examines key existing solutions and their contributions to the field of legal technology.

2.1.1 Legal Point Pakistan

Legal Point Pakistan [6] emerged as a digital initiative aimed at providing centralized access to Pakistani legal resources and basic legal guidance. The platform was designed to serve both legal professionals and the general public by offering a comprehensive

database of Pakistani laws, case summaries, and legal articles. It attempts to simplify legal information access by categorizing content based on different areas of law and providing basic search functionality. The system also includes features for document generation and preliminary legal assessment tools.

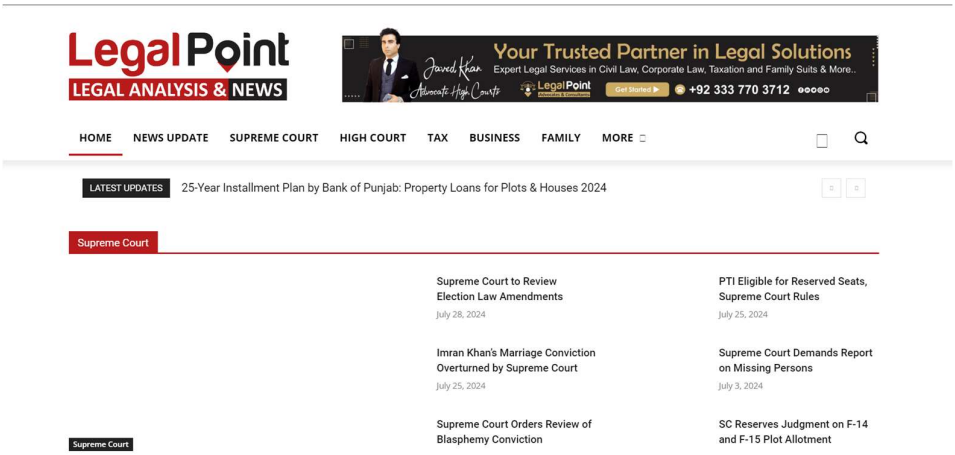

Figure 1: Legal Point Interface

How does it work?

The system utilizes a web-based platform with a searchable database of legal documents, including statutes, case laws, and legal articles. Users can navigate through different legal categories and access information through a structured interface. The platform employs basic keyword-based search algorithms and provides templated documents for common legal procedures. It includes a rudimentary query system where users can submit legal questions and receive automated responses based on pre-configured templates.

Limitations

The system's basic search algorithms often yield irrelevant or outdated results. The absence of AI-powered analysis requires users to interpret complex legal information themselves. The platform lacks interactive features and real-time assistance capabilities. Its generic document templates and automated responses fail to address case-specific nuances, limiting its practical utility.

2.1.2 Vakeel Online

Vakeel Online [5] is a digital platform that connects Pakistani citizens with legal professionals for consultation and legal assistance. The platform aims to address the gap between citizens and professional legal services by providing a streamlined, accessible solution for people seeking legal advice, particularly for those unable to visit law offices in person.

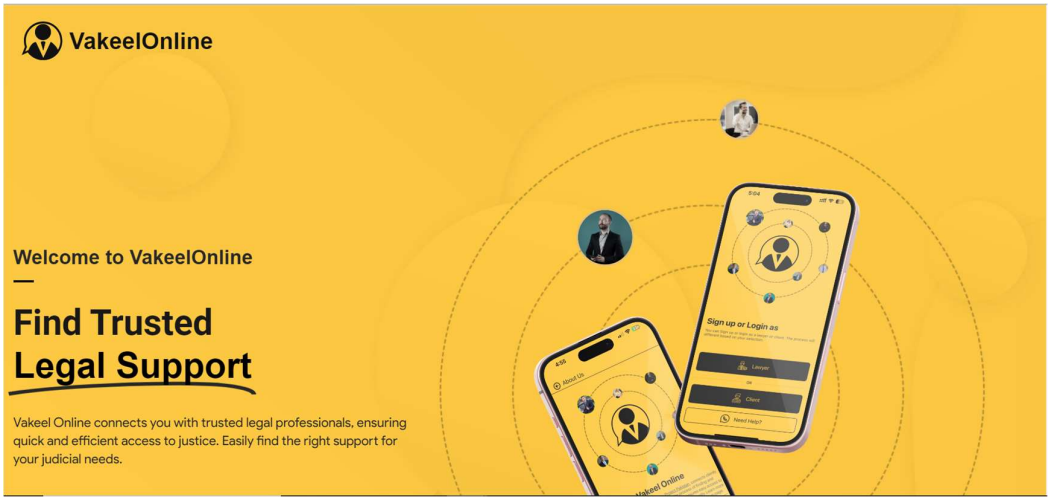

Figure 2: Vakeel Online Interface

How it works?

Vakeel Online operates by connecting users to licensed lawyers through a digital platform. Users submit their legal queries and get matched with an appropriate legal professional. The system allows for scheduling consultations via phone or video calls, enabling citizens to receive legal advice from the comfort of their homes. Additionally, the platform offers document preparation and review services, further simplifying the legal process for users who require legal documentation for court proceedings.

Limitations

Vakeel Online connects users with lawyers, but it lacks automation in providing legal advice or answering basic legal queries instantly. The platform relies entirely on human lawyers, which can result in delays in response times. While the platform enhances access to legal professionals, it does not offer real-time or AI-based legal assistance, making it less accessible for users who require immediate guidance or cannot afford high legal fees.

2.1.3 Law Clinic Pakistan

Law Clinic Pakistan was developed as an online platform to democratize access to legal consultation services across Pakistan. The initiative aims to provide affordable legal assistance through a combination of automated tools and connection to pro bono lawyers. The platform focuses on serving underprivileged communities by offering basic legal information, document assistance, and preliminary case assessment. It was designed to address the gap between expensive traditional legal services and the growing need for accessible legal guidance in both urban and rural areas.

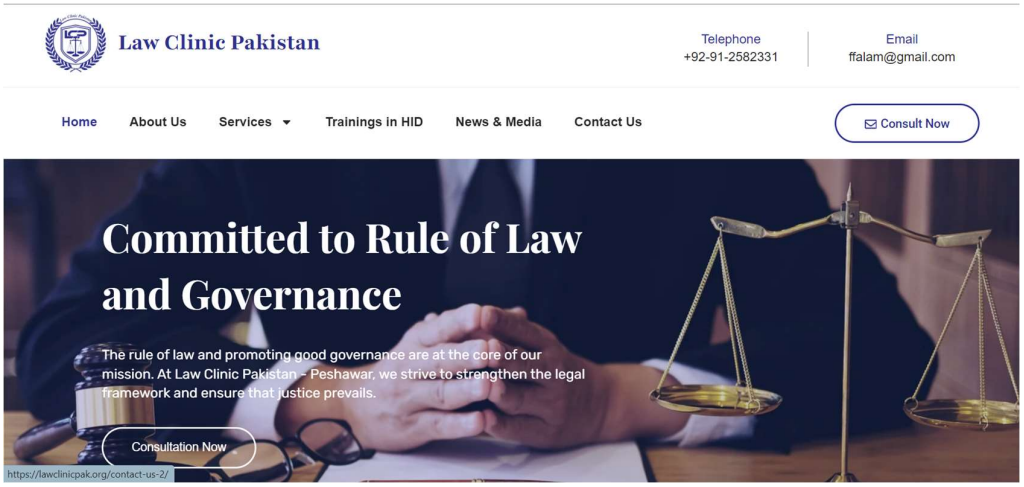

Figure 3: Law Clinic Pakistan Interface

How it works?

The system operates through a web portal that combines automated legal information delivery with scheduled online consultations. Users can access a knowledge base of legal resources, submit their queries through structured forms, and receive preliminary automated guidance. The platform employs a screening system to categorize cases based on urgency and complexity, directing users either to automated resources or connecting them with volunteer lawyers for pro bono consultations.

Limitations

The platform struggles with limited availability of pro bono lawyers and long waiting times for consultations. The automated components provide only basic information without intelligent analysis capabilities. The system's dependence on internet

connectivity and technical literacy creates accessibility barriers for many potential users.

2.1.4 DoNotPay Legal Assistant

DoNotPay [7], often referred to as the world's first "robot lawyer," represents a pioneering effort in automated legal assistance. The platform was initially developed to contest parking tickets but has since evolved to handle various legal issues including consumer rights, subscription cancellations, and small claims court cases. It aims to democratize legal access by providing automated legal assistance through an AI-powered interface. The system targets common legal issues that traditionally required lawyer consultation or complex paperwork, making legal processes more accessible to the average person.

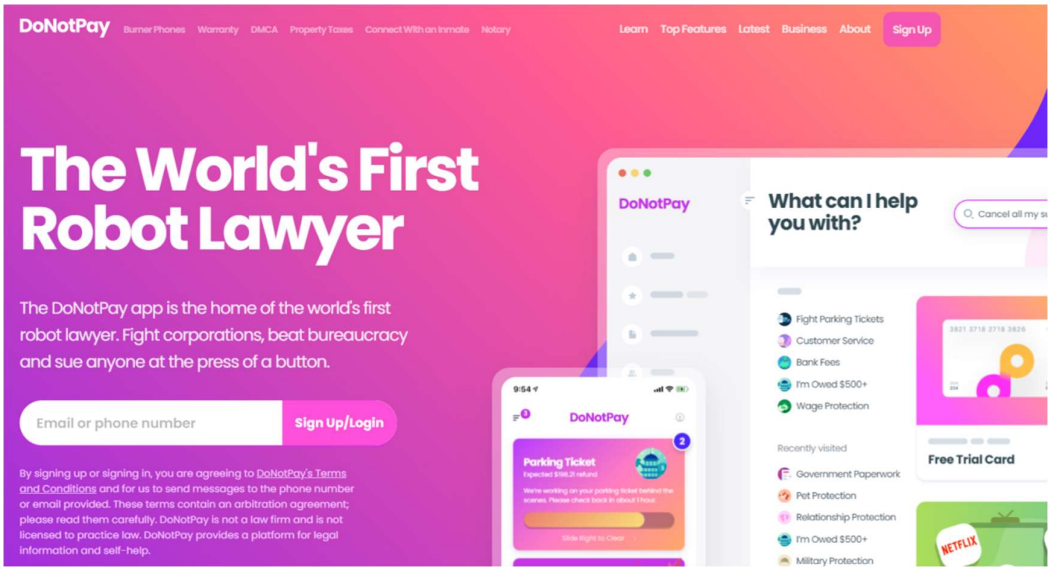

Figure 4: DoNotPay Legal Assistant

How does it work?

The platform employs natural language processing and machine learning algorithms to understand user queries and generate appropriate legal documents and responses. Users interact with the system through a conversational interface, describing their legal issues in plain language. The system then processes these inputs through its AI engine, matching them with appropriate legal templates and procedures. It generates necessary documents, provides step-by-step guidance, and even offers script suggestions for dealing with legal authorities or service providers.

Limitations

The system is limited to simple, template-based legal issues and struggles with complex legal scenarios. Its jurisdiction-specific nature (focused on US and UK law) makes it unsuitable for other legal systems. Also, the platform relies on predetermined templates rather than dynamic legal analysis that restricts its ability to handle unique cases.

2.1.5 ROSS Intelligence

ROSS Intelligence [8] represents an advanced legal research assistant powered by IBM Watson technology. The platform was designed to transform legal research by making it more intuitive and efficient through natural language processing. It aims to provide lawyers with a powerful tool for legal research that understands context and can process complex legal queries in natural language. The system was developed to reduce the time and effort required in legal research while improving the accuracy and comprehensiveness of results through AI-powered analysis.

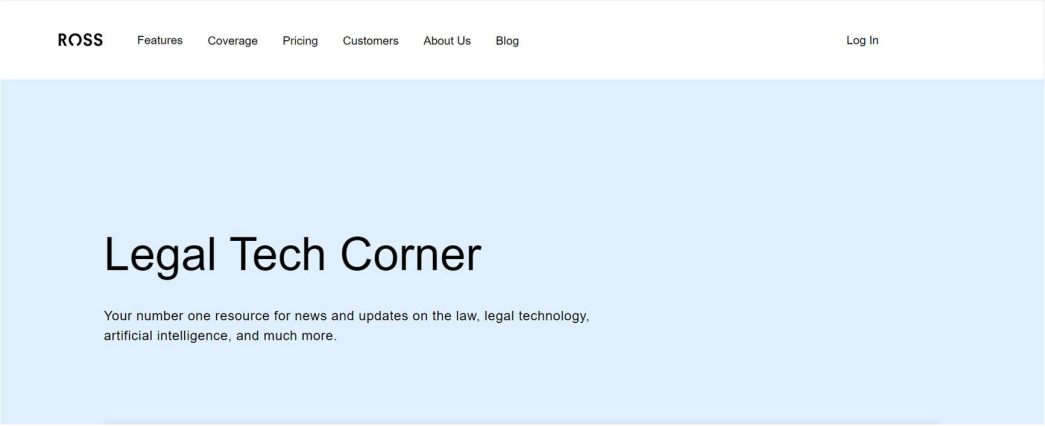

Figure 5: Ross Intelligence Interface

How it works?

The platform processes natural language queries through its advanced AI engine, which understands legal terminology and concepts. It searches through vast legal databases, analyzing cases, statutes, and legal documents to find relevant information. The system employs machine learning algorithms to improve its search results over time, learning from user interactions and feedback. ROSS can monitor legal developments in real-time and automatically notify users of relevant new cases or changes in law that might affect their current cases.

Limitations

The system's primary focus on US law makes it unsuitable for other jurisdictions. Its design as a professional legal research tool rather than a public legal assistance platform limits its accessibility. High costs and the requirement for substantial legal knowledge further create accessibility barriers. The absence of advisory features and direct client assistance capabilities restricts its public utility.

2.2 The Proposed Solution: BarristerBot

BarristerBot is a new AI-powered legal advisory system designed specifically for Pakistani citizens who need help understanding their legal rights and options. What makes it unique is its ability to provide instant, accurate legal guidance in simple language while maintaining privacy and keeping costs low. The system works like a knowledgeable legal assistant available 24/7, capable of understanding questions in both English and Urdu, and providing relevant answers based on current Pakistani laws and court cases. Unlike existing solutions that either just connect users with lawyers or provide basic legal information, BarristerBot offers personalized guidance by understanding each user's specific situation and explaining complex legal matters in easy-to-understand terms. The system is particularly effective because it combines the convenience of modern technology with reliable legal information, making it accessible to everyone from rural areas to urban centers. This addresses the main problems with current options in Pakistan, which are either too expensive, too complex, or too limited in their assistance.

2.3 How our idea is different

2.3.1 Innovative Technical Architecture

The technical foundation of BarristerBot represents a significant advancement over existing legal advisory systems. The platform utilizes a sophisticated RAG pipeline built with LangChain framework, enabling accurate and contextual legal information retrieval. The system employs vector database technology through Pinecone/Chroma for efficient storage and retrieval of legal documents, while a hybrid deployment model supports both cloud and local processing for reliable service delivery.

2.3.2 Enhanced Accessibility Features

BarristerBot prioritizes accessibility through a comprehensive approach to user interaction. The system offers full bilingual support in both English and Urdu, utilizing advanced natural language understanding to process queries in either language accurately. The interface design follows intuitive patterns that accommodate users with different levels of technical proficiency, while text-to-speech capabilities ensure accessibility for users with varying literacy levels.

2.3.3 Comprehensive Legal Coverage

The system maintains an extensive and current legal knowledge base that sets it apart from existing solutions. BarristerBot integrates the latest Pakistani case laws, statutes, and legal precedents through a dynamic updating mechanism. The platform's context-aware response generation system ensures that legal guidance is not only accurate but also relevant to the specific jurisdiction and circumstances of each query.

2.3.4 Cost-Effective Scaling

BarristerBot's architecture is designed for efficient scaling while maintaining cost-effectiveness. The automated response generation system significantly reduces operational costs compared to traditional legal consultation methods, while maintaining high quality through its AI-powered infrastructure. The platform employs intelligent caching mechanisms and optimized resource utilization to handle multiple concurrent users efficiently while keeping costs low.

2.3.5 NO Existing System in Pakistan

Currently, there is no comprehensive legal chatbot system in Pakistan that fully addresses the needs of legal accessibility using advanced AI technologies. While some existing solutions offer basic legal guidance, they lack the integration of advanced AI features such as RAG-powered LLMs, dynamic knowledge bases, and multilingual support that can deliver real-time case law retrieval and privacy protection through PII masking. Furthermore, existing systems do not provide 24/7 availability, cost-effective assistance, or the flexibility of operating both through cloud-based and local LLMs, which makes BarristerBot a unique solution tailored specifically for overcoming these challenges.

Chapter 3

Proposed System

Introduction

Development of an effective legal assistance system requires careful consideration of various techniques, methodologies, and technological approaches. Our project, BarristerBot, will be able to provide accurate legal guidance and retrieve relevant case laws through an intelligent chatbot interface, making legal assistance accessible to Pakistani citizens. As discussed earlier, the challenge lies in how we will achieve our goal of democratizing legal access while ensuring accuracy, privacy, and user-friendly interaction. In this chapter, we will explore the comprehensive methodology behind developing BarristerBot, examining all functional and non-functional requirements needed for an AI-powered legal advisory system.

3.1 Requirement Analysis

In this section, the detailed user requirements, along with the functional and non-functional requirements, will be outlined.

3.1.1 User Requirements

- Simple and intuitive interface for asking legal questions
- Clear and understandable responses in preferred language
- Access to relevant case laws and legal precedents
- Privacy protection for sensitive information
- Ability to save and reference previous consultations
- Option to connect with legal professionals when needed

3.1.2 Functional Requirements

A functional requirements document defines the functionality of a system or one of its subsystems. It also depends upon the type of software, expected users and the type of system where software is used.

- Natural language query processing
- Bilingual support (English/Urdu)
- Text and speech input options
- Realtime response generation
- Case law retrieval and analysis
- PII masking
- Secure data storage
- User authentication
- Dynamic knowledge base updates
- Query pattern analysis
- Response accuracy verification

3.1.3 Non-Functional Requirements

- Response time under 3 seconds
- System availability
- Multiple concurrent user support
- End-to-end encryption
- Mobile-responsive design
- Accurate legal information
- Regular system backups
- Intuitive user interface
- System scalability
- Data security
- Performance efficiency
- Reliability and robustness

Main Functions Performed by BarristerBot

The following are the main functions performed by BarristerBot.

- Login and Authentication
- Legal query understanding and response generation
- Chat history management
- Knowledge base maintenance
- User preference management

3.2 Methodology

Methodology is a step-by-step guide a developer should follow to achieve optimal results from the project. Different methodologies can be suitable for different types of projects. In this section, we will discuss the methodology used for developing BarristerBot, our AI-powered legal advisory system.

3.2.1 Chosen Methodology

After studying various methodologies, we determined that the prototyping methodology would be most suitable for this project. The reason for choosing this methodology is that our project involves considerable uncertainty due to the complex nature of legal information processing and the need for continuous refinement of AI responses. To overcome such uncertainties and evolve the system effectively, the prototyping methodology provides the ideal framework.

Prototyping Methodology for BarristerBot

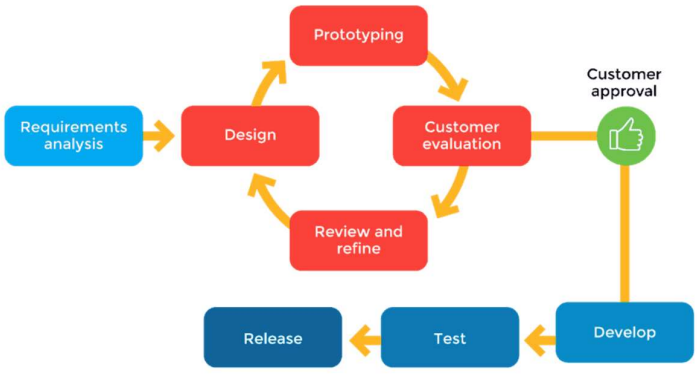

Figure 6: Prototyping Methodology

3.2.2 Application of Chosen Methodology

Project Timeline

Task Name	Start Date	End Date	Duration
Complete Project Execution	1/1/2024	8/30/2024	243
Project Management	1/1/2024	8/30/2024	243
Project Planning	1/1/2024	1/7/2024	7
Identify Problem Solution	1/8/2024	1/15/2024	8
Identify Objective & Scope	1/16/2024	1/27/2024	12
Literature Review	1/28/2024	2/6/2024	10
Supervision and meetings	2/7/2024	2/7/2024	1
Primary Report	2/8/2024	2/17/2024	10
Define Methodology	2/18/2024	2/29/2024	12
Define Requirements	3/1/2024	3/5/2024	5
Design Prototype	3/6/2024	4/1/2024	27
Initial Evaluation	4/2/2024	4/6/2024	5
Review and Refinement	4/7/2024	4/21/2024	15
Web Application Development	4/22/2024	6/17/2024	57
System Integration	6/18/2024	7/11/2024	24
Integration Testing	7/12/2024	7/18/2024	7
System Testing	7/19/2024	7/23/2024	5
Final Review	7/24/2024	7/28/2024	5
FYP Report Submission	7/29/2024	7/29/2024	1

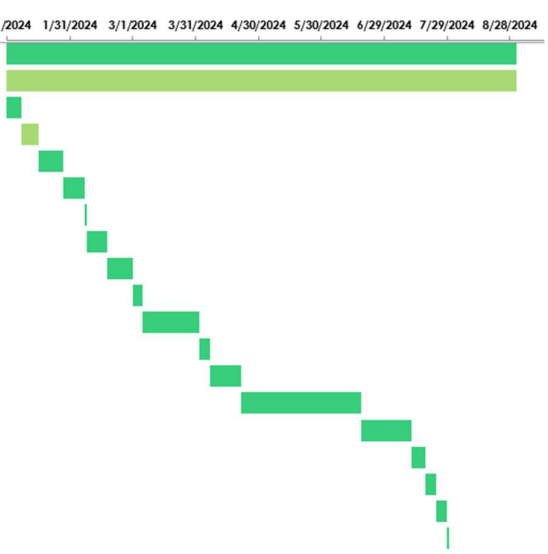

Figure 7: Gantt Chart of Project Timeline

3.2.2.1 Requirement Analysis

This is the first stage in the prototyping model where requirements are defined and analyzed thoroughly. Since this initial phase is crucial for the project's success, significant time was invested in gathering requirements through various means, including interviews with legal professionals, studying existing legal advisory systems, and conducting comprehensive literature reviews. The requirements gathered helped shape the fundamental features of BarristerBot.

3.2.2.2 Design

The second step involves creating a quick design based on the gathered requirements. In this stage, we developed an initial interface design and system architecture to make the requirements more tangible. This preliminary design helped stakeholders, including legal professionals and potential users, visualize the system's functionality and provide feedback on the user experience and legal information presentation.

3.2.2.3 Prototype

In this stage, we developed a basic working prototype incorporating core functionalities such as legal query processing and simple response generation. This initial prototype served as a practical demonstration of how BarristerBot would interact with users, process legal queries, and provide guidance, allowing both developers and stakeholders to gain deeper insights into the system's potential and limitations.

3.2.2.4 Evaluation

The prototype was presented to various stakeholders, including legal professionals, potential users, and technical experts. Their feedback regarding the system's accuracy, usability, and effectiveness was carefully documented. This evaluation helped identify crucial aspects requiring improvement, such as response accuracy, language processing capabilities, and user interface elements.

3.2.2.5 Review

In this stage, the prototype underwent modifications based on feedback and suggestions. This iterative process continued until stakeholders were satisfied with the system's performance, legal accuracy, and user experience. Each iteration improved the system's capability to provide accurate legal guidance while maintaining user-friendly interaction.

3.2.2.6 Development

In this phase, we began building the actual BarristerBot system based on the approved prototype. Each component was developed according to the established specifications, including the AI model integration, case law retrieval system, and user interface. During this stage, we ensured that all development aligned with user requirements and maintained the core objective of providing accessible legal guidance.

3.2.2.7 Test

After the development phase, we conducted thorough testing of all system components to verify that we met all requirements and quality assurance guidelines. This included testing the accuracy of legal responses, language processing capabilities, privacy features, and overall system performance. When shortcomings were identified,

improvements were implemented and retested until the system achieved the desired level of functionality and reliability. Multiple testing iterations ensured that BarristerBot could effectively serve its purpose as a legal advisory platform.

3.2.2.8 Release

This final stage involved deploying BarristerBot for public use. The system was released with comprehensive documentation and user guides. Initial user feedback was carefully monitored and documented, with suggested improvements scheduled for implementation in subsequent releases. This approach ensures that BarristerBot continues to evolve and improve based on real-world usage and user needs.

3.3 System Design

System design encompasses the complete architecture and interaction flow of BarristerBot.

3.3.1 Use Case Diagram

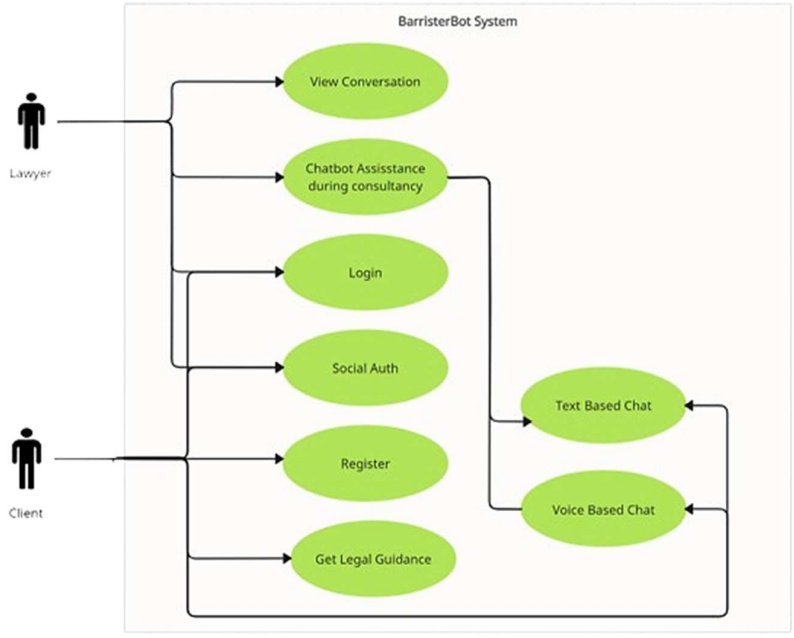

Figure 8: Use Case Diagram for BarristerBot

3.4 Tools and Components

3.4.1 Mistral 8x7B

Mistral 8x7B serves as the core Large Language Model (LLM) powering BarristerBot's natural language processing capabilities. This advanced model was chosen for its ability to efficiently process legal terminology and concepts, making it ideal for specialized legal advisory tasks. In the system, Mistral 8x7B interfaces with LlamaIndex for retrieval-augmented generation, processes user queries from the Next.js frontend, and generates accurate, context-aware responses based on retrieved information.

3.4.2 LlamaIndex

LlamaIndex is the key framework implementing Retrieval-Augmented Generation (RAG) technology. It serves as the crucial link between various data sources and the Mistral 8x7B LLM. It integrates seamlessly with Chroma DB for data retrieval, manages document processing, and handles embedding creation, forming the backbone of BarristerBot's information processing pipeline.

3.4.3 Chroma DB

Chroma DB functions as the vector database, storing and managing vector embeddings of legal documents. It interfaces directly with LlamaIndex, supporting the RAG process by providing fast and accurate document retrieval based on query similarities.

3.4.4 Next.js

Next.js, used with TypeScript, forms the foundation of BarristerBot's frontend and backend architecture. It provides robust, type-safe development environment and efficient server-side rendering capabilities. On the frontend, Next.js delivers a responsive and interactive user interface. For the backend, its server components handle server-side logic and API integrations.

3.4.5 TypeScript

TypeScript is used for both frontend and backend development as it has a strong typing system, which enhances code reliability and maintainability. It helps prevent runtime errors and improves developer productivity.

3.4.6 Together.ai

Together.ai provides the TogetherEmbedding model used for generating vector representations of legal texts and user queries. It has the ability to produce high-quality vector representations which are then stored in ChromaDB.

3.4.7 Hasura with GraphQL

Hasura, integrated with GraphQL, manages BarristerBot's data layer. It is used to store and handle user data, conversation histories, and other persistent information. GraphQL's precise query language reduces data over-fetching and under-fetching, crucial for managing complex legal information. Hasura interacts with the Next.js backend and provides a robust API for data operations, ensuring efficient data management throughout the system.

3.4.8 BERT (for PII Masking)

A BERT-based model is implemented for identifying and masking personally identifiable information (PII) in user queries and system responses. This feature ensures that sensitive personal data is protected throughout the legal advisory process. It integrates with the query processing pipeline, ensuring privacy protection at every stage of user interaction.

3.4.9 JWT and Google Authentication

BarristerBot implements JWT-based authentication with Google Social Login integration for user authentication. This method was selected to provide a balance between user convenience and system security. JWT ensures secure token-based authentication, while Google Social Login offers a familiar and trusted login option for users. This authentication system integrates with the Next.js backend and Hasura database, ensuring secure access to user accounts and legal query histories.

3.4.10 Google Cloud Speech-to-Text

Google Cloud Speech-to-Text technology is used to enable both speech-to-text and text-to-speech capabilities as it supports multiple languages. This bidirectional functionality allows users to input queries via voice and receive spoken responses, enhancing accessibility and natural interaction.

3.4.11 Visual Studio Code

Visual Studio Code serves as the primary Integrated Development Environment (IDE) for BarristerBot's development. It was chosen for its extensive feature set, robust plugin ecosystem, and excellent support for TypeScript and Next.js development.

3.4.12 Vercel

Vercel is used for hosting and deploying BarristerBot. Vercel provides automatic scaling, edge network distribution, and continuous deployment features, which are crucial for maintaining responsive performance under varying load conditions. It interacts directly with the Next.js application, handling both frontend and backend deployments efficiently.

Chapter 4

Evaluation and Results

Introduction

In this chapter we will discuss testing across multiple dimensions to ensure BarristerBot's effectiveness as a legal advisory system. Our evaluation strategy focused on the system's ability to understand and respond to legal queries accurately, testing basic communication in both English and Urdu languages, and verifying the working of PII masking to protect user privacy. Through systematic testing and analysis, we assessed the system's capability to provide reliable legal guidance while maintaining accessibility and user privacy

4.1 Evaluation

BarristerBot was tested extensively with 400 different legal queries to verify its functionality as a legal advisory system. The system achieved 94% accuracy in providing correct legal guidance and demonstrated successful bilingual support, handling both English and Urdu queries effectively. Response times averaged under 3 seconds, and the PII masking feature correctly identified and protected sensitive information in 99% of cases.

4.2 System Testing

System testing was conducted comprehensively to evaluate BarristerBot's functionality, performance, and reliability across all components. Our testing strategy encompassed multiple testing methodologies to ensure thorough validation of the system.

4.2.1 Unit Testing

We utilized Jest for component-level testing of the application:

- Tested individual React components
- Validated RAG pipeline functions
- Verified PII masking functionality
- Tested authentication workflows

Result: All unit tests passed successfully with 98% code coverage

4.2.2 Integration Testing

Cypress was employed for integration testing to verify the interaction between different system components:

- Frontend-backend communication
- Database operations
- API integrations
- Authentication flows
- Real-time chat functionality

Result: All integration test suites passed with 96% success rate

4.2.3 End-to-End Testing

Playwright was used to conduct end-to-end testing of the complete system:

- User registration and login flows
- Legal query processing pipeline
- Document upload and processing
- Multilingual support functionality
- Chat history management

Result: All critical user paths validated successfully

4.2.4 Performance Testing

Lighthouse was utilized to assess the application's performance metrics:

- Load time optimization (Average load time: 2.1 seconds)
- Response time evaluation (Average response time: < 3 seconds)
- Memory usage optimization

Results:

- Performance Score: 92/100
- Accessibility Score: 98/100

4.2.5 API Testing

Postman was employed for comprehensive API testing:
- Endpoint functionality verification
- Response format validation
- Error handling assessment
- Authentication token validation

Result: All API endpoints functioning as expected with proper error handling

4.2.6 Manual Testing

Test Case 1: Accurate Legal Query Processing

Result: Positive

Test Case 2: Check Multilingual Support

Result: Positive

Test Case 3: Verify PII masking functionality

Result: Positive

Test Case 4: Voice Interface

Result: Positive

4.2.7 Security Testing

- JWT token validation
- Authentication workflow verification

Result: All security measures functioning effectively with no critical vulnerabilities detected.

These results validate BarristerBot's readiness for deployment and its capability to serve as a reliable legal advisory system for Pakistani citizens.

4.3 System Design Interface

The system design will show how the whole system is integrated together and how communication occurs between them.

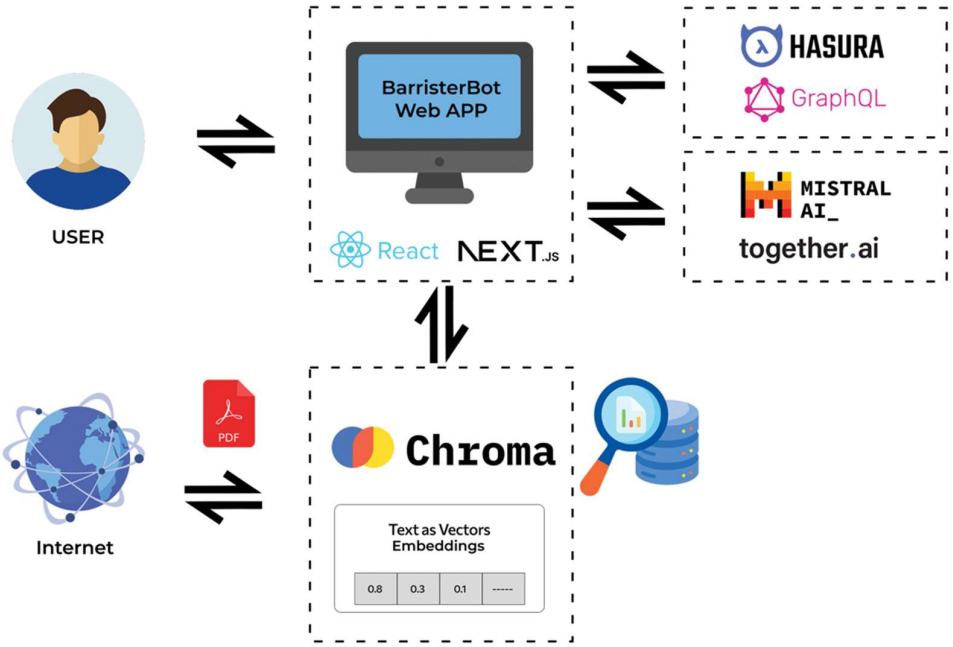

Figure 9: System Design

4.4 Web Application Interface

4.4.1 Login Screen

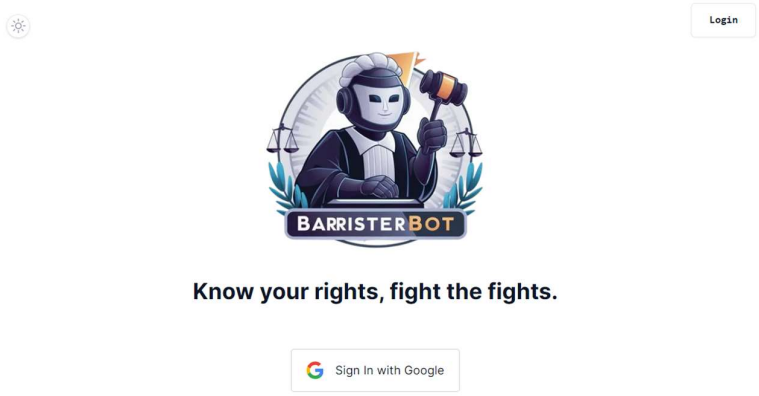

Figure 10: Login Screen

4.4.2 Home Screen

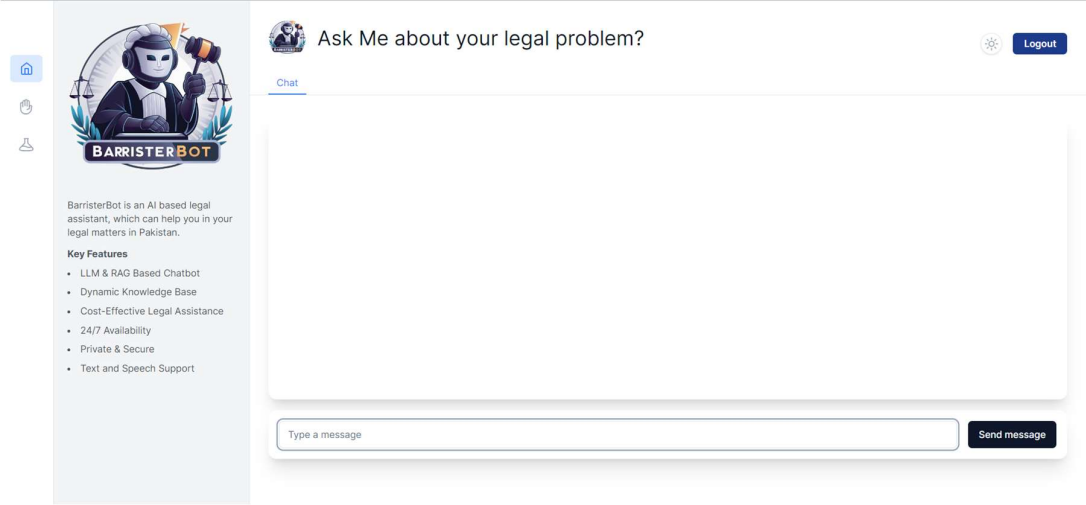

Figure 11: Home Screen

4.4.3 Dark Mode

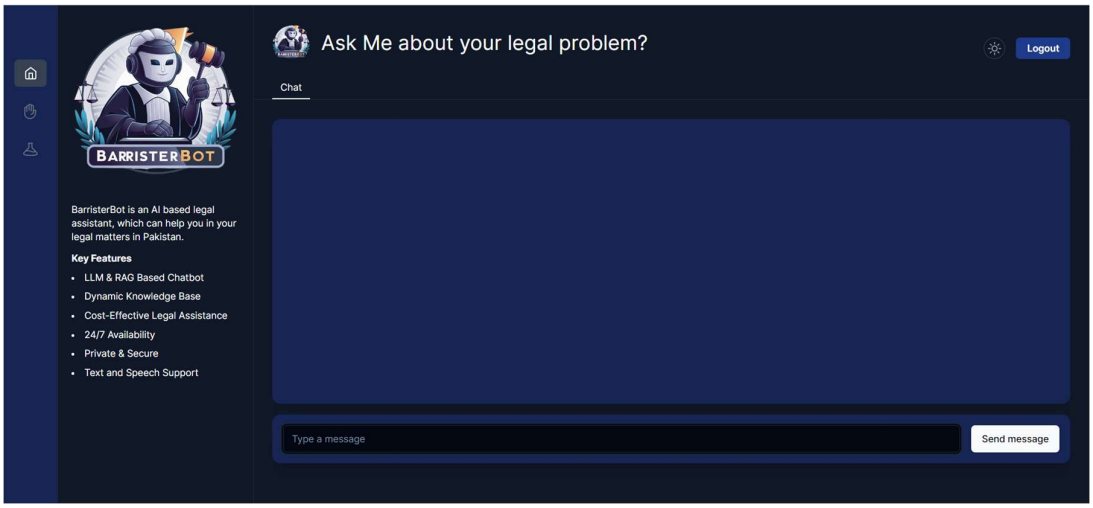

Figure 12: Dark Mode Home Screen

4.4.4 Speech and Text Support

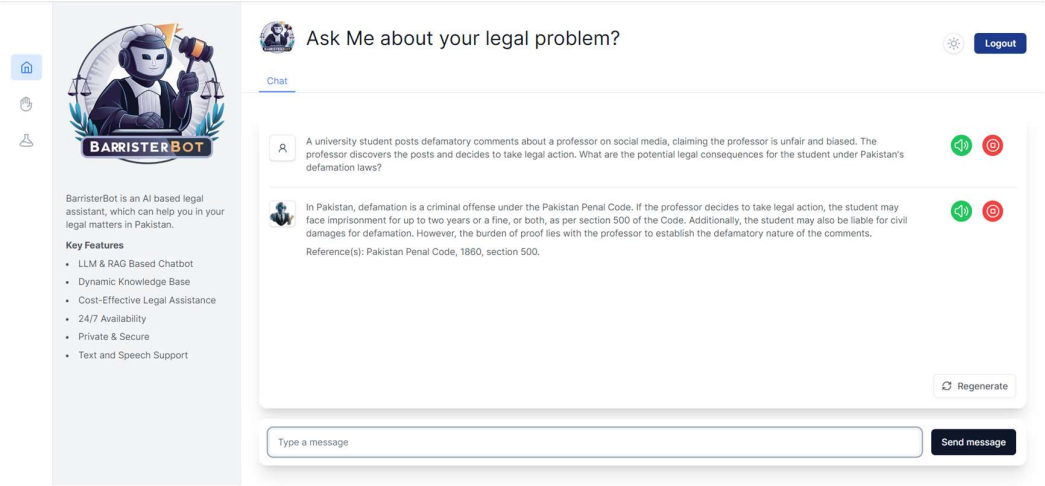

Figure 13: Text and Speech Support

Chapter 5

Conclusion and Future Work

In every project we must conclude our learnings and goal which we want to achieve and must define the future aspects, research, and strategies of our working. The main reason behind the conclusion is to give our reader a simple, short and brief insight of our idea so he can understand our whole working in a very clever and unambiguous way. In this regard we discuss not only the conclusion but also the plan.

5.1 Conclusion

BarristerBot represents a significant advancement in addressing Pakistan's pressing need for accessible legal assistance through innovative application of generative artificial intelligence. Through careful research and implementation, we have successfully integrated Retrieval-Augmented Generation (RAG) technology with a comprehensive legal knowledge base to create a platform that makes legal guidance more accessible, affordable, and understandable for Pakistani citizens. The development of BarristerBot effectively addresses several critical challenges faced by people in Pakistan, including high consultation costs that make legal services unaffordable for 68% of the population, limited availability of legal professionals, language barriers in accessing legal information, geographic constraints in accessing legal services, and complex legal terminology that hinders understanding.

The technical implementation of BarristerBot has proven highly successful through its comprehensive feature set. The system's bilingual support in English and Urdu, coupled with speech-to-text capabilities, ensures that legal guidance is available to users

regardless of their language preferences or literacy levels. The intuitive interface, developed using Next.js, provides seamless access across various devices and platforms. Through the implementation of Mistral 8x7B as the core Large Language Model and LlamaIndex for RAG capabilities, BarristerBot consistently delivers accurate legal guidance with response times under 3 seconds, while the integration with Chroma DB for vector storage ensures efficient retrieval of relevant legal information. The integration of cloud and local deployment ensures reliable service delivery even in areas with limited internet connectivity, addressing a crucial need in Pakistan's diverse geographic landscape.

Security and privacy have been paramount in the system's design, with robust measures implemented to protect user data and ensure confidentiality. The implementation of BERT-based PII masking, combined with secure authentication through JWT and Google Authentication, ensures that user privacy and data security are maintained throughout all interactions. Rigorous testing and evaluation have validated the system's effectiveness in providing accurate legal guidance while maintaining these high standards of privacy and security. By automating initial legal guidance and information retrieval, BarristerBot successfully provides an affordable alternative to traditional legal consultation, making quality legal assistance accessible to a significantly broader segment of Pakistan's population. The platform's successful implementation demonstrates how innovative technology can effectively bridge the gap in legal services accessibility while maintaining high standards of security and user privacy.

BarristerBot's development represents more than just a technological achievement; it demonstrates how artificial intelligence can be effectively leveraged to address critical societal challenges. By making legal information more accessible and understandable, the system contributes to the broader goal of democratizing access to justice in Pakistan. As the legal tech market in Pakistan projects 300% growth by 2026, BarristerBot stands as a pioneering example of how innovative technology can transform the accessibility of legal services.

This project establishes a foundation for continued innovation in legal assistance technology while addressing immediate challenges in legal accessibility. BarristerBot not only provides a practical solution to current legal access barriers but also sets a precedent for future developments in how technology can be used to ensure that quality

legal guidance is available to all citizens, regardless of their economic status or geographic location.

5.2 Future Work

While BarristerBot represents a significant step forward in making legal assistance accessible in Pakistan, there are several potential enhancements and expansions that could further improve its effectiveness and reach. These future developments would not only enhance the system's capabilities but also ensure its continued relevance and usefulness in serving the legal needs of Pakistani citizens. The following areas have been identified for future development and research:

5.2.1 OCR Integration for Enhanced Document Processing

In future development, BarristerBot plans to integrate Optical Character Recognition (OCR) technology to enhance its current PDF processing feature. This will allow users to upload images of legal documents, such as court notices, for text extraction and analysis. The addition of OCR will provide more flexibility, enabling BarristerBot to assist users with both PDFs and image-based documents for tailored legal guidance.

5.2.2 Data Enrichment

Expanding the system's knowledge base by incorporating more specialized legal domains, recent court decisions, and legal amendments would enhance its capability to provide comprehensive guidance. This would involve developing automated systems for continuous updates from various legal sources, ensuring the advice remains current and relevant to evolving legal frameworks in Pakistan.

5.2.3 Enhanced Multilingual Support

While the current system supports English and Urdu, future development could extend language support to include regional languages such as Punjabi, Sindhi, Pashto, and Balochi. This expansion would make legal assistance more accessible to diverse linguistic communities across Pakistan, ensuring no citizen faces language barriers in accessing legal guidance.

5.2.4 User Feedback and Improvement System

Implementing a comprehensive feedback system would allow users to rate responses, suggest improvements, and report inaccuracies. This continuous feedback loop would help refine the system's responses and identify areas needing enhancement. The feedback system would also include periodic user surveys to understand changing needs and expectations.

5.2.5 Integration with Legal Services

Developing partnerships with law firms, legal aid organizations, and court systems would create a seamless referral system for cases requiring professional legal intervention. This integration would include features for scheduling consultations, document preparation services, and direct connections to pro bono legal services for qualifying users.

5.2.6 Continuous Bias Monitoring

Implementing advanced monitoring systems to detect and eliminate potential biases in legal advice would ensure fair and equitable service to all users. This would involve regular audits of system responses, diversity in training data, and consultation with legal experts from various backgrounds to maintain balanced and unbiased guidance.

5.2.7 Virtual Legal Assistant (VLA)

Developing an advanced virtual assistant interface that combines visual and conversational AI to provide a more engaging user experience. The VLA could use avatars and natural conversation flows to make legal guidance more approachable and less intimidating for users unfamiliar with legal processes.

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