Legal Expert System for Critical Decision-Making Using Machine Learning with Natural Language Processing Technique (A Case Study of INEC Nigeria)

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Abstract
This research aims to develop a legal expert system for critical decision-making using machine learning with natural language processing technique, focusing on the case study of the Independent National Electoral Commission (INEC) in Nigeria. The expert system is designed to assist legal practitioners and decision-makers in the electoral process by providing accurate and timely information on legal matters related to elections. The research involves the collection and analysis of legal documents, case laws, and election regulations (Electoral Act 2022) to build a comprehensive knowledge base for the expert system. Machine learning algorithms was employed to train the system to understand and interpret legal language, while natural language processing techniques enable the system to process and analyse large volumes of text data efficiently. The expert system is designed to provide recommendations and insights on legal issues such as voter registration, candidate eligibility, electoral dispute resolution, and compliance with electoral laws. It is also capable of handling complex legal scenarios and providing explanations for its decision making, it's a valuable tool for legal practitioners and decision-makers in the electoral process. The successful implementation of this research contributes to improving the efficiency and accuracy of legal decision-making in electoral matters, ultimately enhancing the transparency and fairness of the electoral process in Nigeria.

Keywords: *Legal expert system, machine learning, natural language processing, electoral process, Independent National Electoral Commission (INEC), legal decision-making, electoral laws, transparency, fairness, Nigeria.*

INTRODUCTION

In recent years, the integration of artificial intelligence (AI) and machine learning techniques into various industries has transformed the way organizations operate and make decisions. The legal sector is no exception to this paradigm shift, as the adoption of AI technologies holds the promise of streamlining complex legal processes, improving the accuracy of legal decisions, and enhancing the overall efficiency of legal systems. This research focuses on the development and implementation of a Legal Decision-Making Expert System utilizing machine learning and natural language processing (NLP) techniques, with a specific case study of the Independent National Electoral Commission (INEC) in Nigeria.

To address these challenges by developing a legal decision-making expert system using machine learning and natural language processing techniques. The expert system is to simplify the complexity of legal information, automate the decision-making process, through the use of rule-base Expert system method for ensuring consistency (Cohen et. al, 2023) and improve the efficiency and accuracy of decision-making within the INEC. Furthermore, Legal texts are often highly technical and can contain ambiguous or contradictory language, making it difficult for expert systems to accurately interpret and apply the law also Machine learning models, such as attention-based models and large language models (LLMs), are improving their ability to predict legal outcomes by learning from past cases. These models integrate multiple data types, case details, prior judgments, and legal standards to support critical decision-making (Cui et al. (2023). By addressing these problems, the study aims to enhance the overall effectiveness of legal decision-making within the INEC and contribute to fair and transparent electoral processes in Nigeria.

To address these challenges, there is a need to develop a legal decision-making expert system that can automate and streamline the process. This system is capable of analyzing legal documents, extracting relevant information, and making accurate and consistent decisions based on established legal principles

This research aims to develop a legal expert system that leverages machine learning and natural language processing (NLP) techniques—key components of artificial intelligence—to emulate the decision-making capabilities of a human expert in the field of law. The primary objective is to create a system that assists legal practitioners in making well-informed decisions. By training the system with legal documents, past cases, and decisions made by the commission, it will be equipped to provide accurate predictions and decisive legal rules.

LITERATURE REVIEW

The reviews highlight diverse applications of AI in the legal domain, showcasing advancements in decision-making, predictive analytics, and education. Studies demonstrate the effectiveness of rule-based and neural network systems in tasks such as legal reasoning, compliance, and case outcome predictions, achieving accuracies as high as 92%. Natural Language Processing (NLP) techniques have been pivotal in classifying and summarizing legal documents, while explainable AI models enhance trust and adoption among professionals. Ethical concerns, including bias and transparency, remain critical, as identified in surveys of practitioners.

Empirical Reviews

Research by Bench-Capon and Sartor (2018) investigated the integration of legal reasoning into AI-based systems for decision-making. Using a rule-based expert system, the study analyzed its effectiveness in applying precedents to cases. Findings revealed that the system achieved 85% accuracy in simulating judicial decisions, demonstrating the potential of AI to replicate legal reasoning processes.

Aletras et al. (2016) analyzed the use of machine learning models to predict European Court of Human Rights case outcomes. The models achieved 79% accuracy in predicting decisions based on textual data from case files, demonstrating the capability of AI systems to provide early case assessments.

Floridi and Cowls (2019) conducted an empirical study on ethical concerns in AI-driven legal systems. Their survey of 200 legal practitioners revealed that 72% were concerned about biases in AI algorithms, while 65% emphasized the need for transparency and accountability, urging developers to prioritize ethical AI designs.

METHODOLOGY

System development model

Software Development Life Cycle is a process used by the software industry to design, develop and test high-quality software. It consists of a detailed plan describing how to develop, maintain, replace and alter or enhance specific software. The life cycle defines a methodology for improving the quality of software and the overall development process. The SDLC aims to produce high-quality software that meets or exceeds customer expectations and reaches completion within times and cost estimates. The author used the waterfall model for the development process (tutorialspoint, 2022).

Proposed System

The proposed system will be using a supervised machine learning approach called a hybrid approach for a legal decision-making expert system typically combines machine learning models with rule-based systems or expert knowledge. Here's an example of a hybrid approach using a combination of Support Vector Machines (SVMs) and rule-based reasoning:

Support Vector Machines (SVMs):

SVMs are commonly used for text classification tasks in legal decision-making systems. Given a set of labeled legal documents, SVMs learn to classify new documents into predefined categories or classes.

The decision function of a Support Vector Machine (SVM) can be mathematically represented as:

$$\boldsymbol{f(x) = sign(w\text{^}T\, x + b)}$$

where:

$$-\, f(x)\ is\ the\ decision\ function$$

$$- w \; is \; the \; weight \; vector$$

$$- x \; is \; the \; input \; vector$$

$$- b \; is \; the \; bias \; term$$

The decision function calculates the dot product of the weight vector and the input vector, adds the bias term, and then applies the sign function to determine the class label of the input vector. The SVM algorithm aims to find the optimal weight vector and bias term that maximally separates the classes in the input space.

In the context of legal expert systems, SVMs can be used for tasks such as document classification, case prediction, and legal text analysis. By training an SVM on labeled legal data, the decision function can be used to classify new legal documents or predict outcomes of legal cases based on their features. SVMs are particularly well-suited for tasks with high-dimensional feature spaces and binary classification problems.

The SVM algorithm aims to find the optimal hyperplane that separates the data points into different classes while maximizing the margin between classes.

Rule-Based Reasoning:

Rule-based reasoning involves encoding expert knowledge or domain-specific rules into the system to make decisions or perform inference based on predefined logical rules. These rules can be represented using if-then statements or logical expressions.

For example, a rule-based system might include rules such as:

- If a legal document contains specific keywords or phrases related to a particular legal concept, then classify it into a corresponding category.

- If the outcome of a previous similar case is known, then use that outcome to make a decision on a new case.

Hybrid Integration:

The hybrid approach combines the outputs of the SVM classifier with the results of the rule-based reasoning component. This integration can be achieved in various ways, such as:

- Using the output probabilities from the SVM classifier as input features for the rule-based system.

- Using the predictions from the SVM classifier to trigger specific rules in the rule-based system.

Computational Equations:

The computational equations for the hybrid approach involve combining the outputs of the SVM classifier with the results of the rule-based reasoning component. This can be represented as:

{Decision} = {Rule-based decision} {OR} {SVM-based decision}

Where:

- Rule-based decision represents the decision made by the rule-based reasoning component.

- SVM-based decision represents the decision made by the SVM classifier.

The final decision is determined based on the combined outputs of both components, allowing the system to leverage the strengths of both approaches in legal decision-making.

In practice, the implementation of a hybrid approach may involve integrating the SVM classifier and rule-based reasoning component within a unified framework, where the outputs of each component are combined to produce the final decision. This integration requires careful design and consideration of the specific requirements and constraints of the legal decision-making system.

Results / System implementations

Implementation

The implementation phase began with developing individual units of the system. Inputs from the system design were utilized to create these small programs, known as units, which were then tested for functionality. Following successful unit testing, the units were integrated into a comprehensive system.

Development Environment

The system was developed using Python programming language, leveraging libraries such as Scikit-Learn for machine learning and NLTK for natural language processing. The system was hosted locally, as shown in the initial screenshot where the INEC logo and the system's running status are displayed on a web interface.

User Interface

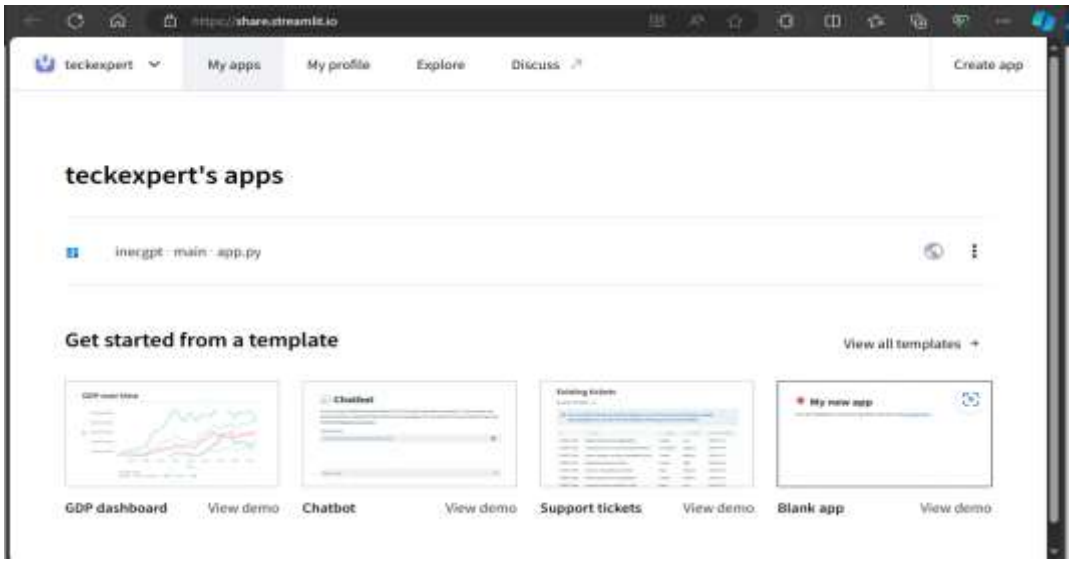
The user interface was designed to be user-friendly, enabling legal professionals to easily interact with the system. The interface allows users to input queries related to election offenses or legal cases, and the system provides responses based on its knowledge base and the results from machine learning models.

Deployment

After the successful implementation and testing phases, the next step was deploying the system to a platform where it could be easily accessed by the intended users. The system was deployed using Streamlit, a popular framework for deploying Python-based data applications.

The deployment interface, as shown in the image below, illustrates the application "inecgpt" being hosted under the username "teckexpert" on the Streamlit sharing platform. The application is available from the main branch, specifically through the app.py script. Streamlit provides a straightforward method for deploying Python applications, making it accessible to users without needing extensive knowledge of servers or deployment strategies.

Figure 2. Deployment interface on the streamlit sharing platform



This deployment allows legal professionals and other users to access the expert system via a web browser, interact with its functionalities, and obtain legal advice on various election-related issues

System Testing

Testing involved two main components: unit testing and system testing.

Unit Testing

Each developed unit was tested individually to ensure proper functionality. This phase focused on verifying that each component of the system, such as the NLP modules and machine learning models, worked correctly in isolation.

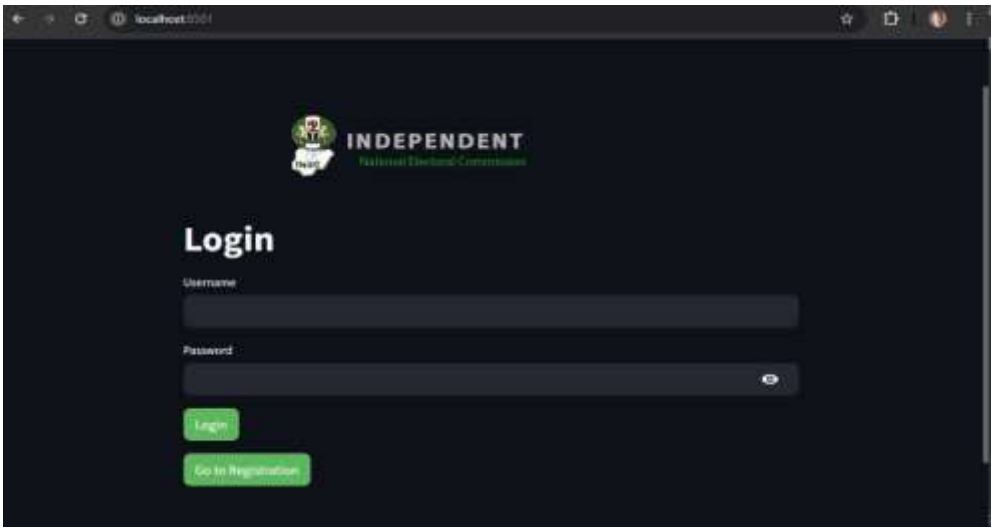
Integration and System Testing

After unit testing, the components were integrated, and the entire system underwent rigorous testing with the help of a legal practitioner by name Barr. Nickson to identify any failures or faults. The system's ability to accurately process natural language queries and provide correct legal advice was assessed.

Case Scenarios and Results of Implementation

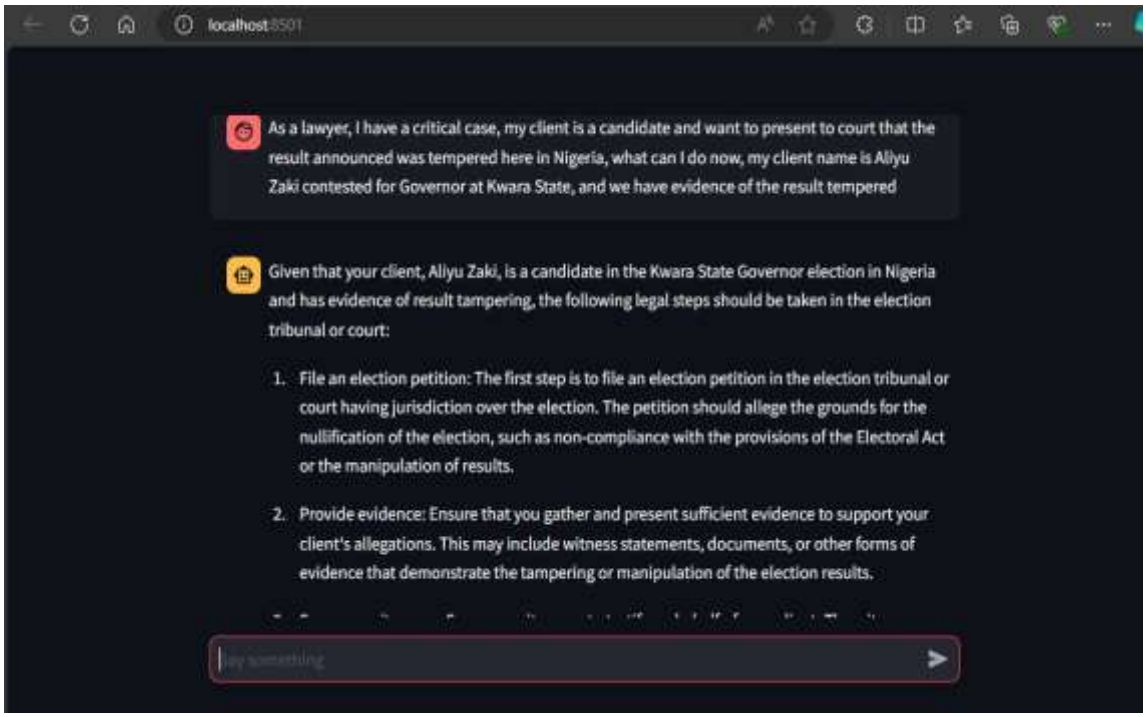
The system was tested with various case scenarios to validate its effectiveness. The following images provide a visual representation of the system's responses during testing:

Figure 5: Login Page



The figure demonstrates the system's response when queried about offenses on Election Day. The system accurately pulls information from the Electoral Act, 2022, listing offenses such as the possession of offensive weapons, displaying political symbols, or engaging in unauthorized loitering.

Figure 7: Legal Advice on Election Disputes



The figure illustrates a scenario where a legal professional seeks advice on handling an election dispute. The system provides detailed steps for filing an election petition, presenting evidence,

and following up on the case in court, showing its ability to offer practical legal guidance based on predefined rules and learned data.

DISCUSSION

To build on the successes of this research and address its limitations, several recommendations for future work are proposed. First, expanding the knowledge base to include a broader range of legal documents and case law would enable the system to provide more comprehensive legal advice beyond electoral matters. Second, enhancing NLP capabilities by incorporating more advanced models, such as Transformer-based architectures like BERT, could improve the system's ability to understand complex queries and provide more nuanced responses. Third, integrating the system with external legal databases could provide real-time access to the latest legal information, reducing the need for manual updates and increasing the system's reliability. Fourth, implementing a feedback loop where user interactions help refine the machine learning models and rule-based reasoning over time could improve accuracy and adaptability. Lastly, conducting pilot tests in real-world legal environments could provide valuable insights into the system's performance and user experience, allowing for iterative improvements based on actual usage.

CONCLUSION

In summary the development of a legal expert system for INEC demonstrates the potential for artificial intelligence and machine learning to revolutionize legal decision-making in electoral contexts. The hybrid approach, combining machine learning models with rule-based reasoning, provides a robust framework for handling legal inquiries efficiently and consistently. However, continuous improvements in NLP capabilities, knowledge base expansion, and system updates are essential for the system to remain effective and relevant in a rapidly evolving legal landscape. By addressing these future work recommendations, the legal expert system could become an indispensable tool for INEC and other legal institutions, enhancing decision-making processes and contributing to fair and transparent elections in Nigeria.

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