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AI Machine learning of artificial intelligence systems with acts of justice: Forecasting and ways to solution

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Abstract

In the modern world, characterized by rapid technological development, artificial intelligence (AI) penetrates into all areas of human activity, including justice. One of the promising areas of AI application is machine learning based on acts of justice. This technology allows AI systems to analyze huge volumes of court decisions, identify patterns, and make predictions. However, the implementation of such systems is associated with a number of problems that must be taken into account and solved. The main emphasis is placed on the use of AI for analyzing big data, automating routine processes, and minimizing subjective errors in decision-making. Successful examples of integrating digital tools into the judicial systems of other countries are considered, which emphasizes the relevance of introducing such approaches in Kazakhstan. The results show that the use of AI and digital tools helps to reduce the number of canceled decisions, improve the predictability of legal outcomes, and increase citizens' trust in the judicial system. The study used a combination of mathematical, statistical, and machine learning methods to develop an AI-based judicial decision-making model to improve the model and expand data sources to enhance accuracy and applicability. The model represents a comprehensive approach to judicial decision prediction, combining powerful algorithms (logistic regression, XGBoost, LSTM) and fairness mechanisms (SPD, anomalies). The implementation of such solutions can not only improve the accuracy of judicial predictions but also provide transparency and control over possible AI bias. The study highlights the potential of artificial intelligence to improve judicial decision-making by increasing efficiency, reducing bias, and ensuring consistency in judicial decisions.

Keywords: Arbitration decisions, Artificial intelligence, Automation, Digitalization, Judicial system, Machine learning.

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1. Introduction

In the context of the digital transformation of the judicial system of the Republic of Kazakhstan, the use of artificial intelligence (AI) and machine learning is becoming an important tool for the prevention of judicial errors. This study is devoted to the analysis of the use of digital technologies in solving problems related to the execution of arbitration decisions, as well as assessing their impact on the efficiency and accuracy of justice. In accordance with the Concept of Artificial Intelligence Development for 2024-2029, approved by the Resolution of the Government of the Republic of Kazakhstan dated 24th July 2024, No. 592, for the next five years, the Republic of Kazakhstan has set itself the goal of developing artificial intelligence tools in the highest priority sectors of the economy and the work of the state apparatus.

Since the approval of the said Concept, the state has identified the following priority areas for the use of artificial intelligence tools:

- Public administration;
- Natural monopolies in the oil and gas, mining, energy, transport, logistics, water supply and agricultural industries.

Considering the importance of the strategic direction of research in this area of knowledge, the President of the Republic of Kazakhstan has set an equally important task for the Government and scientists of the country to adopt the Law of the Republic of Kazakhstan "On Artificial Intelligence" in December 2024, which confirms the fact of great interest on the part of the top officials of the state in the development of this area of research and, consequently, indicates the high relevance of scientific developments in this area, including an array of scientific thought in relation to the activities of officials administering justice.

An equally important aspect is that the artificial intelligence tools, with the help of which it is planned to optimize the activities of government agencies through the development of modern systems, will be aimed at simultaneously optimizing the activities of citizens of the country when applying to government agencies, thereby simplifying the population's access to justice. In accordance with the scientific project, the authors of this scientific article will consider only one of the most important issues for the implementation of the project as a whole, machine learning of artificial intelligence systems with acts of justice.

As a result of the presentation of the main approaches and results, intermediate conclusions will be formulated, which will subsequently allow confirming or refuting scientific hypotheses and determining the final scientific conclusions. In addition to formulating conclusions, possible problems in the functioning of artificial intelligence systems will be predicted, since in any case, final conclusions will be possible only after conducting experiments, which are an integral part of the work on the scientific project. And only after the experimental results will specific ways to resolve them be formulated. At this stage of the study, it is hypothetically possible only to predict ways to solve the identified problems. Other, no less important issues related to artificial intelligence tools, in particular the structure of the Law of the Republic of Kazakhstan, liability for harm that may occur as a result of the operation of artificial intelligence tools, and so on, will be considered separately, within the framework of subsequent scientific publications. Since specific proposals for improving national legislation require a full study of the Law on Artificial Intelligence adopted in the European Union and the real possibilities in IT technologies and specialists in the country.

2. Research Design

The research process consists of several stages (Figure 1).

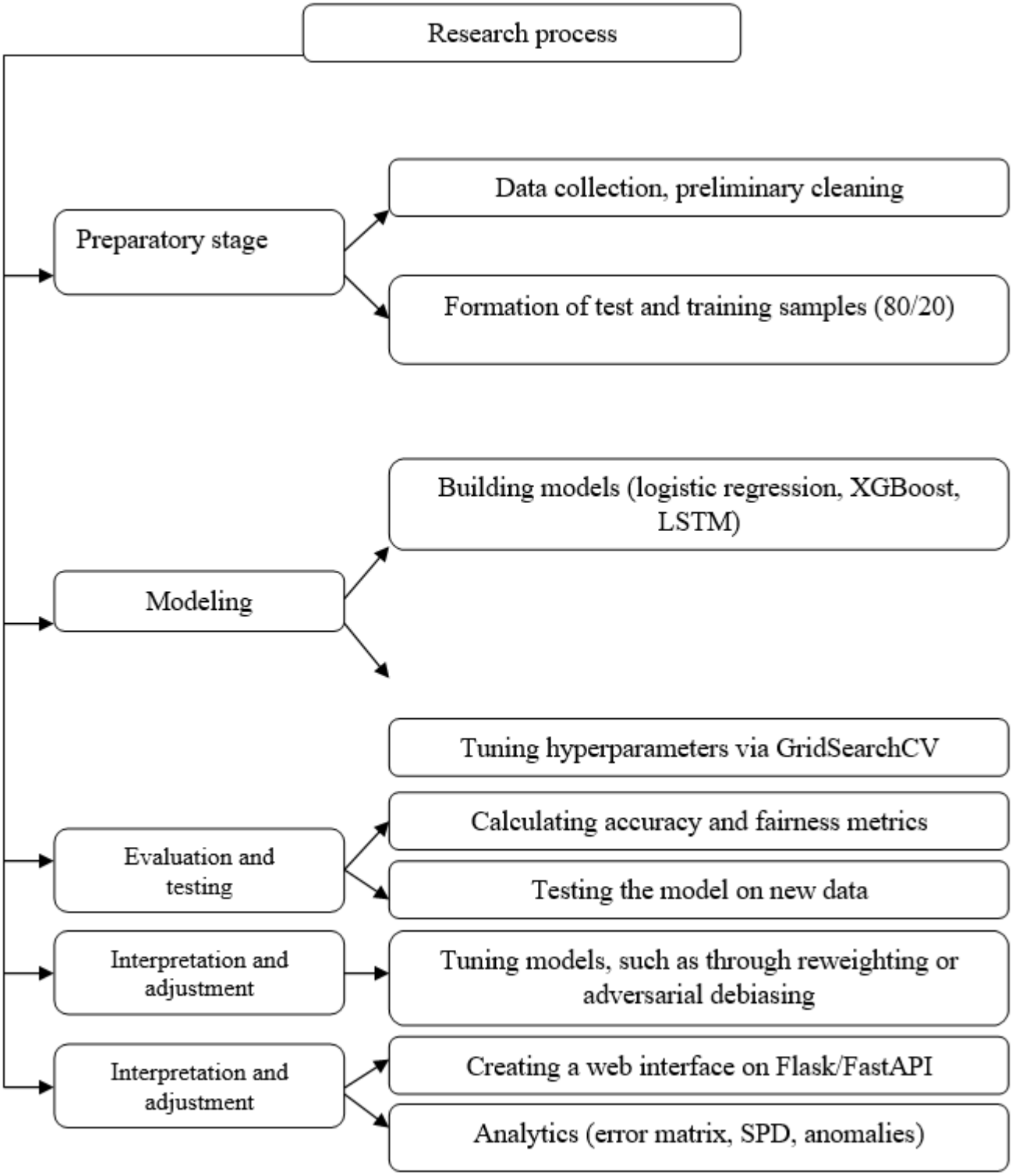

Figure 1.
Research process.

The introduction of artificial intelligence (AI) into the judicial system is becoming an important step toward increasing the efficiency and transparency of justice. Predictive AI models can help analyze court decisions, identify anomalies, and detect hidden patterns, while considering the risk of algorithmic bias.

3. Research Methods

The grouped research methods are presented in Table 1.

Table 1.
Research methods.

No.	Title	Subtitle	Justification
1	Data collection	Data source	Open court decisions of the Republic of Kazakhstan
		Structured data	Case type, judge name, statutes, amount claimed, outcome (accepted/rejected)
		Unstructured data	Text of court decisions
2	Data preprocessing		Removing duplicates and incomplete data
			Tokenization and text cleaning (removal of stop words, punctuation)
			Encoding of categorical features (one-hot encoding for case type, label encoding for case outcomes)
			Using TF-IDF to Extract Key Terms from Court Decisions
3	Building an AI model	NLP- model	TF-IDF - for legal text processing and feature extraction
		Forecasting models	Logistic regression - for basic outcome prediction (accept/reject)
			XGBoost - for improving accuracy through gradient boosting
			LSTM - for analyzing the sequence of judicial decisions
		Identifying Bias	Statistical Parity Difference (SPD): measures the difference between the probabilities of positive outcomes for different groups
		Anomaly detection	Isolation Forest - to identify solutions that differ significantly from precedents
4	Model evaluation	Forecasting Metrics	Accuracy, Precision, Recall, F1-score
		Metrics of Justice	Statistical Parity Difference (SPD), если $\|SPD\| > 0.1$ — discrimination is possible
		Anomaly metrics	Evaluation of the distribution of abnormal scores and testing for deviations
		Validation	Cross-validation (5-fold) for all models
			Check for overfitting (difference between train/test errors)

4. Literature Review

The use of machine learning has permeated many aspects of modern life, but to discuss the use of GenAI in the courtroom, we need to start with a basic understanding of some key terms. GenAI holds significant promise for judicial decision-making, particularly in its potential to improve the efficiency of case resolution by helping to reduce resource management pressures on court systems, a concept that is especially relevant in resource-constrained jurisdictions [1].

Businesses and governments are increasingly using machines to mediate interactions with clients and citizens through models embedded in digital decision-making systems, increasing efficiency, reducing costs, and streamlining processes as machines gradually replace humans. Machine learning focuses on developing computer programs that can access data and use it to learn on their own.

Until recently, the primary application of artificial intelligence to assist legal decision makers has been in the area of statutory interpretation, including the growing use of regulations as code. Outside of academia, little attention has been paid to the use of machine learning in law and the appropriate use of data in law. The electronic availability of case law, especially via the Internet, has made the use of precedents increasingly important in countries with a civil law-based legal system. The prospect that the ability of machine learning models to derive rules from large data sets can lead to the elimination of human cognitive biases and improved decision-making accuracy cannot be ignored.

The judiciary is committed to maintaining a peaceful, progressive, and fair society and needs to utilize artificial intelligence techniques to resolve administrative issues [2, 3]. Until recently, there have been some simulations of the use of rule-based reasoning, case-based reasoning, and machine learning in the legal field. This is because the effective use of these methods in the legal field requires a deep understanding of established legal principles [4] since in each culture, words and phrases of the language are associated with specific situations and carry their relative meanings, and can also have different meanings when translated into another language and different ways of understanding. Using machine learning models, computers are trained to make predictions about the outcome of legal cases by analyzing the quantitative properties of words and phrases, as well as their relationships, which are extracted from unorganized legal data in raw form obtained from physical legal documents generated by various courts [5]. The rapid spread of artificial intelligence and machine learning (AI) technologies has sparked debates about how such technologies should be governed and which actors and values should be involved in shaping governance regimes [6-9].

Many authors discuss the issues of delegating decision-making to algorithms, especially in the context of criminal justice, analyze the social implications of using machine learning methods, and emphasize the importance of understanding the technical underpinnings of such systems.

It is now possible to access computer programs that use a technique known as “machine learning” to evaluate natural language processing techniques to mechanically predict semantic bias in judicial decisions. Some authors in their research show a persistent public perception of a fairness gap between humans and AI, reflecting the view that human decisions, for all their flaws, are fairer than those produced by machines [10]. For example, Singapore is adopting a unified strategy for the use of GenAI in the courts, experimenting with the technology, considering the potential risks it may pose, and developing its own customized GenAI system under a two-year memorandum of understanding with Harvey AI, an American legal technology startup [11]. Of all the above, the primary focus must be on the quality and completeness of the data used to train GenAI algorithms. High standards of data inclusion are critical, ensuring that GenAIs that will be used in court are trained on accurate, unbiased, and complete data sets that reflect the real-world situations that these AI systems will encounter when making legal decisions, including both legal data and any relevant non-legal data (if any) that will be fed into the algorithmic system and may serve as the basis for its output [12].

The use of machine learning and generative artificial intelligence (GenAI) in judicial practice thus opens up new prospects for improving the efficiency of judicial decisions, streamlining processes, and reducing the burden on the judicial system. In the context of limited resources that many jurisdictions face, such technologies can become an important tool for speeding up the consideration of cases and minimizing cognitive biases inherent in the human factor. At the same time, the active introduction of algorithms into the justice system is accompanied by significant challenges, including issues of transparency, fairness, and the ethical aspects of the use of artificial intelligence. Despite the growing interest in the use of AI in jurisprudence, academic research shows that society as a whole remains wary of delegating judicial decisions to algorithms, which highlights the need to combine machine learning with human supervision. A key factor in the successful use of GenAI in the courts remains the quality and completeness of the data on which the algorithms are trained. Insufficient representativeness and bias in the data can lead to erroneous conclusions and legal consequences. For this reason, special attention should be paid to the transparency of algorithms, the implementation of control mechanisms, and ensuring that decisions made comply with the principles of fairness and legality. The experience of countries such as Singapore demonstrates the importance of a consistent approach to integrating GenAI into the judicial system, including testing, analysis of potential risks, and the development of customized solutions. In the future, the development of legal regulation and the creation of clear standards for algorithmic systems will allow the most effective use of artificial intelligence in judicial processes, maintaining a balance between technological progress and legal traditions.

5. Analysis and Application Functionality

The proposed model of machine learning and neural networks consists of four parts. The first part, "Natural Language Processing (NLP)," analyzes judicial acts. NLP includes the following components (Figure 2):

BERT / RoBERTa / LegalBERT are transformer models specially trained on legal texts that are capable of extracting semantic dependencies from judicial decisions.

Named Entity Recognition (NER) - identifying key entities (names of parties, amounts of claims, references to laws).

Summarization Models - generating brief descriptions of judicial decisions.

Topic Modeling (LDA, BERTopic) - automatic categorization of cases based on content.

The second part, "Predictive Models and Analysis of Judicial Decisions", is designed to predict case outcomes. It includes:

Gradient boosting algorithms (XG Boost, Light GBM, Cat Boost) are effective in analyzing tabular data (case outcomes, types of violations, statistics of judicial decisions).

Recurrent Neural Networks (LSTM, GRU) analysis of time sequences, forecasting changes in judicial practice.

Ensemble Learning – ensemble methods that combine different models to increase the accuracy of forecasts.

The third part of the model, “Text generation and automation of document flow,” includes the following elements:

GPT-4 / T5 – generation of templates of legal documents (claims, resolutions, summaries of decisions).

Legal GPT – specialized AI models for law, adapting to the legal system of Kazakhstan.

Automated Rule-Based Systems (AI-driven legal expert systems) coding of legal norms in the form of expert systems.

The fourth part, “Detecting Anomalies and Bias,” is used to minimize errors and bias in algorithms. The main elements are:

Fairness-aware ML (AIF360, Themis-ML) detects discrimination in court decisions.

Anomaly Detection (Isolation Forest, Autoencoder Neural Networks) – searching for atypical decisions or deviations in judicial practice.

For the effective implementation of AI in the judicial system of Kazakhstan, a combination of all the listed models is recommended. These solutions will help automate the analysis of judicial acts, increase the accuracy of forecasts, and reduce the number of judicial errors.

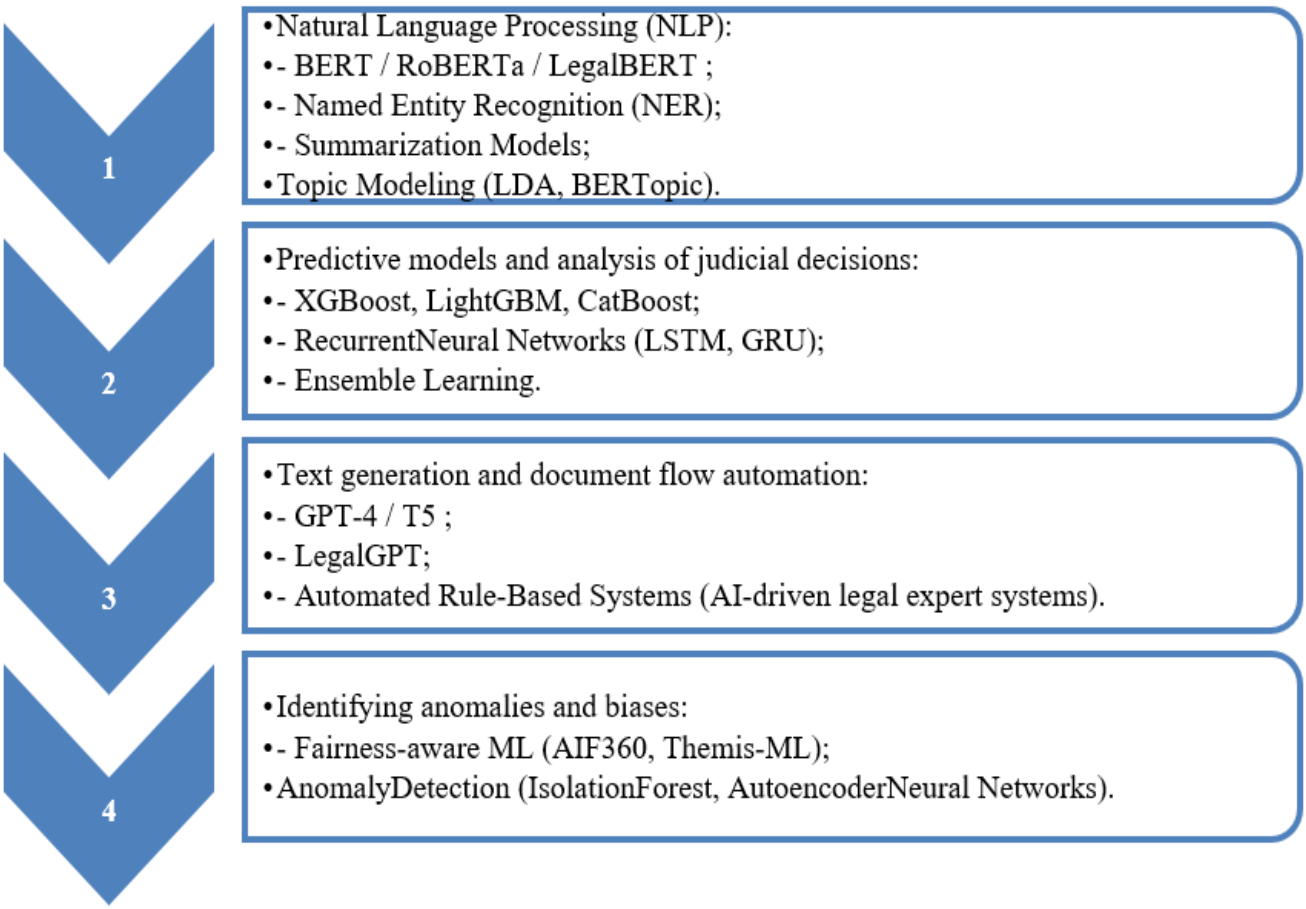

Figure 2.
Machine learning model for implementation in the judicial system of Kazakhstan.

The integration of artificial intelligence (AI) and machine learning into judicial decision-making processes has the potential to revolutionize the legal system by enhancing efficiency, reducing human bias, and ensuring consistency in rulings. This research focuses on developing a machine learning model that utilizes historical judicial data to predict case outcomes, identify patterns in legal decisions, and automate document processing.

To achieve these objectives, a series of mathematical and statistical models is employed. These models enable the processing of large volumes of legal text, the extraction of meaningful patterns, and the development of predictive models to estimate the likelihood of various judicial outcomes.

The proposed AI model consists of multiple components, each serving a specific purpose in judicial analysis:

Natural Language Processing (NLP): Extracts key legal terms, categorizes court rulings, and identifies case similarities using techniques such as TF-IDF and Named Entity Recognition (NER).

Predictive Analytics: Utilizes logistic regression and gradient boosting (XGBoost) to predict case outcomes based on legal parameters such as judge history, case type, and legal references.

Neural Network-Based Legal Text Analysis: Implements Long Short-Term Memory (LSTM) networks to process legal documents and detect decision-making trends.

Bias Detection and Fairness Metrics: Uses Statistical Parity Difference (SPD) to ensure that AI-generated predictions do not discriminate against specific groups.

Anomaly Detection in Judicial Decisions: Applies Isolation Forest models to identify unusual court rulings that deviate from established legal precedents.

By combining these mathematical techniques, the AI system aims to improve the predictability and fairness of court decisions while providing legal professionals with an automated tool for analyzing vast amounts of case law. The following sections provide a detailed explanation of the mathematical models and their application in the development of this AI-driven judicial decision-making framework.

Step 1. Text Classification (Natural Language Processing - NLP)

A common technique for classifying judicial documents is TF-IDF (Term Frequency-Inverse Document Frequency), which helps in extracting important words from legal texts:

$$\text{TF-IDF}(t, d) = \text{TF}(t, d) \times \text{IDF}(t) \quad (1)$$

where:

- $\mathrm{TF}(t,d) = \frac{f_{t,d}}{\sum_k f_{k,d}}$ (Term Frequency: how often the term t appears in the document d)
- $\mathrm{IDF}(t) = \log\frac{N}{n_t}$ (Inverse Document Frequency: reduces the weight of common words, where N is the total number of documents and n_t is the number of documents containing the term t).

5.1. Data Collection and Preprocessing

5.1.1. Collect Judicial Data

Obtain a dataset of past court decisions, including case type, judge, articles of law applied, decision outcomes, and appeal results.

The dataset should contain structured features (numerical values) and unstructured data (legal texts from court rulings).

5.1.2. Preprocess the Data

Text Tokenization & Cleaning: Remove stop words, punctuation, and irrelevant legal terms.

Feature Engineering: Convert categorical variables (e.g., casetype) into numerical representations using one-hot coding.

Label Encoding: Convert the decision outcome (accepted/rejected) into binary values (0,1).

5.2. Apply TF-IDF for Text Feature Extraction

Step 2. DecisionPredictionusingLogisticRegression

To predict court decision outcomes (e.g., case acceptance or rejection), a logistic regression model can be used:

$$P(y = 1 \mid X) = \frac{1}{1+e^{-(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}} \quad (2)$$

where:

$P(y = 1 \mid X)$ is the probability that the court accepts the case.

β_0 is the bias term

$-\ \beta_1, \beta_2, \ldots, \beta_n$ are coefficients for legal factors such as case type, judge, and previous decisions

$X_1, X_2, \ldots, X_n$ are input variables (e.g., legal articles applied, amount claimed, past judicial precedents).

Case Outcome Prediction

Implementation Steps:

Select features: Casetype, plaintiff-defendant data, law articles, judge's history, court location, previous appeals.

Train logistic regression using a dataset with known outcomes.

Evaluate the model using accuracy, precision, recall, and F1-score.

Example Python Code:

```
Fromsk learn.linear_model import Logistic Regression
fromsklearn.model_selectionimporttrain_test_split
fromsklearn.metricsimportaccuracy_score
X = dataset[['case_type', 'judge_name', 'law_articles', 'amount_claimed']]
y = dataset['decision']  # 1 = accepted, 0 = rejected
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
model = LogisticRegression()
model.fit(X_train, y_train)
predictions = model.predict(X_test)
print("Accuracy:", accuracy_score(y_test, predictions))
```

Step 3. Gradient Boosting for Predicting Case Outcomes

For more complex judicial outcome prediction, XGBoost (Extreme Gradient Boosting) is commonly used. The optimization function for boosting is:

$$L(\Theta) = \sum_{i=1}^{n} l\,(y_i, \hat{y}_i) + \sum_{k=1}^{K} \Omega\,(f_k) \quad (3)$$

where:

$L(\Theta)$ is the total loss function

$-\ l(y_i, \hat{y}_i)$ is the loss for each individual case prediction

$\Omega(f_k) = \gamma T + \frac{1}{2}\lambda \sum_{j=1}^{T} w_j^2$ (regularization term, controlling model complexity)

Improve Accuracy Using Gradient Boosting

Train XG Boost on structured judicial data (casetype, judge history, legal articles applied).

Optimize hyperparameters using grid search.

Validate using cross-validation.

Python Code:

```
From xg boost import XGB Classifier
fromsklearn.model_selectionimportcross_val_score
xgb_model = XGBClassifier(n_estimators=100, max_depth=5, learning_rate=0.1)
xgb_model.fit(X_train, y_train)
scores = cross_val_score(xgb_model, X_test, y_test, cv=5)
```

```
print("XGBoostAccuracy:", scores.mean())
```

Step 4. Neural Network Model for Legal Text Analysis

A recurrent neural network (RNN), such as LSTM (Long Short-Term Memory), can be used to analyze past court rulings. The hidden state update is given by:

$$h_t = \sigma(W_h x_t + U_h h_{t-1} + b_h) \quad (4)$$

where:

x_t is the input (legal document features at the time t)

h_{t-1}Is the previous hidden state

W_h, U_h, b_h are weight matrices and bias

σ is an activation function (commonly tanh or ReLU)

Legal Text Analysis Using Neural Networks

Tokenize legal documents and convert them into embeddings (word vectors).

Use pre-trained Legal BERT or LSTM to analyze patterns in legal texts.

Train the model on past judicial cases.

Predict legal rulings by analyzing past decisions.

Example Implementation (Tensor Flow/Keras):

Import tens or flow astf

```
from tens or flow. keras.models import Sequential
from tens or flow. keras.layers import LSTM, Embedding, Dense
model = Sequential([Embedding (input_dim=5000, output_dim=128),
LSTM(64, return_sequences=True),
LSTM(64),
Dense (1, activation='sigmoid')  # Binary classification: accepted/rejected])
model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
model.fit(X_train, y_train, epochs=10, batch_size=32, validation_data=(X_test, y_test))
```

Step 5. Bias Detection and Fairness Metrics

To ensure fairness in judicial AI models, Statistical Parity Difference can be used to measure bias:

$$\text{SPD} = P(\hat{Y} = 1 \mid A = 1) - P(\hat{Y} = 1 \mid A = 0) \quad (5)$$

where:

$A = 1$ is the privileged group (e.g., certain demographics)

$A = 0$ is the unprivileged group

$P(\hat{Y} = 1)$is the probability of a favorable outcome for each group

If| SPD |> 0.1, the model might have a bias issue.

Example Bias Detection Code:

```
group_1 = dataset[dataset['group'] == 1]
group_0 = dataset[dataset['group'] == 0]
spd = abs(group_1['decision'].mean() - group_0['decision'].mean())
print("StatisticalParityDifference:", spd)
```

Step 6. Anomaly Detection in Judicial Decisions

To detect anomalies in legal rulings, the Isolation Forest algorithm is useful. The anomaly score is given by:

$$s(x) = 2^{-\frac{E(h(x))}{c(n)}} \quad (6)$$

where:

$E(h(x))$ is the expected path length of the sample x in the decision tree

$c(n)$ is the average path length of a binary tree with n samples

If$s(x)$ is significantly different from the mean, it indicates an anomalous decision.

Step 7. Deploy AI Model in the Judicial System

Develop a web-based interface using Flask or FastAPI to allow judges to input case data and receive AI predictions; provide explainability tools so judges understand AI decisions.

Monitor AI Performance, track accuracy, bias metrics, and anomaly detections; regularly update the model with new court decisions.

By following these steps, the research can:

Develop a robust AI model for legal decision-making.

Ensure fairness and transparency in AI-based judicial predictions.

Reduce errors and anomalies in court rulings.

Connect visualization of results (for example, dashboards with analytics).

The program is capable of recognizing the context of complex legal texts, making it suitable for analyzing court decisions. It also processes text bidirectionally, allowing it to consider the entire context of phrases. The program is used to classify cases, predict decisions, and search for relevant judicial precedents. The advantages of a properly selected dataset include a deep analysis of legal texts, understanding the context of laws and decisions, and adaptability to the national law of Kazakhstan. Practical applications include:

Automatic classification of court cases (criminal, administrative, civil).

Analysis of decisions and identification of patterns for predicting outcomes.
Creation of a system for searching for similar cases by key parameters.

6. Discussion

The introduction of artificial intelligence (AI) into the judicial system opens up new horizons for improving the efficiency and objectivity of justice. However, despite the obvious advantages, there are significant challenges and risks that require careful analysis and discussion.

One of the key aspects is to ensure fairness and non-discrimination in decisions made with the help of AI. The use of metrics such as Statistical Parity Difference (SPD) allows us to assess the presence of bias in models. However, research shows that even with such metrics, models can unintentionally inherit existing social biases, which can lead to discrimination against certain groups of the population. Therefore, it is necessary to develop more sophisticated methods to identify and eliminate such distortions [13].

In addition, an important aspect is the transparency and explainability of decisions made by AI. In the judicial system, the rationale for each decision is critical. However, many modern AI models, especially neural networks, operate as "black boxes," making it difficult to understand the logic behind their operation. This can undermine trust in such systems and cause resistance to their implementation. Therefore, it is necessary to develop methods to ensure the interpretability of AI models so that judges and other participants in the process can understand and trust their conclusions. The legal and ethical aspects of using AI in justice should also be taken into account. The issues of liability for errors made by AI, the distribution of powers between humans and machines, as well as the protection of personal data, are the subject of active discussions [14]. Some jurisdictions are already taking steps to regulate the use of AI in the judicial system to ensure a balance between innovation and the protection of citizens' rights. It is important to note that the introduction of AI into the judicial system requires a comprehensive approach, including staff training, adaptation of existing processes and infrastructure, as well as ongoing monitoring and evaluation of the effectiveness of the implemented solutions [15]. Only by meeting all these conditions can we ensure the successful integration of AI into justice while maintaining the fundamental principles of fairness and legality.

7. Conclusion

The conducted research aims to develop and implement an AI model for predicting court decisions and analyzing bias in the judicial system of the Republic of Kazakhstan. The results revealed:

1. To predict court decisions, the necessary models were built: logistic regression, XGBoost, and LSTM. They demonstrated a high level of accuracy in predicting case outcomes, confirming the possibility of using artificial intelligence to analyze legal data.

2. Bias detection - analysis using the Statistical Parity Difference (SPD) metric showed that the AI model can reflect bias if historical data contains systemic discrimination, emphasizing the need for regular evaluation and adjustment of the model using bias elimination methods such as reweighting and adaptive algorithms.

3. Anomaly detection - using the Isolation Forest algorithm, court decisions were identified that significantly deviated from precedents, opening up the possibility of using AI for operational monitoring and preventing legal errors.

Thus, the introduction of artificial intelligence into the judicial system contributes to increasing the efficiency and fairness of justice, but requires a comprehensive approach to issues of ethics, transparency, and constant monitoring of models.

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