

Predicting child alimony under Islamic shariah law using hybrid fuzzy inference system

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ABSTRACT

This paper proposes a novel approach to predicting child alimony under Islamic shariah law using a hybrid fuzzy inference system, integrating Mamdani and Takagi-Sugeno-Kang (TSK) fuzzy systems. Machine learning algorithms have become valuable tools for legal decision-making, but judicial process delays can lead to adverse effects. Our model aims to expedite decision-making and minimize legal fees by accurately determining the proper amount of alimony for children after divorce. We collected data from 94 alimony cases and evaluated the model's performance using accuracy, precision, recall, and F1-score metrics. The hybrid fuzzy system achieved promising results with 69% accuracy, 70% precision, 75% recall and 69% F1 score. Notably, the model reduced bias and standardization in decision-making, promoting fairness. However, the study suggests potential areas for improvement and emphasizes trans-parent judgment processes and coordination among judges in assessing alimony costs based on sufficiency and ma'ruf criteria. This research significantly contributes to machine learning applications in the judicial domain. It provides a valuable decision-making tool for judges and lawyers to enhance the judicial process's efficiency and ensure children's welfare in divorce cases under Islamic shariah law. Further research can enhance the model's effectiveness and reliability, opening avenues for continued exploration in this field.

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1. INTRODUCTION

Machine learning algorithms and statistical models are parts of artificial intelligence technology that enable the system to learn from historical training datasets and exhibit the outcome from the test data. Recent advancements in machine learning methods have been beneficial in acting as a tool for decision-making in judicial processes such as litigation, crime cases, tax enforcement, and divorces [1]. Developing decision-making tools is essential to ensuring fast and efficient handling of every action, especially in legal cases. Delaying the judicial process may lead to pernicious effects such as witness hostility, the unfitness of the plaintiff or accused, higher settlement costs due to complex issues, and other adverse impacts [2]. In addition,

any complex issues or disagreements between the plaintiff and the accused may require a longer time for the judicial process, hence the higher cost of legal fees needed [3].

Numerous studies have been conducted using machine learning algorithms to predict the outcome of judicial decisions such as litigation cases, crime, tax evasion, divorce, and parental rights [4]. Decision-making tools aim to predict the outcome of litigation to minimize the cost of legal fees and reduce the number of disputes in court. The main factors in disputes were miscommunication, a limited workforce, non-payment, insufficient specifications and plans, and ineffective site supervision [5].

Rosili *et al.* [4] summarized those previous studies that exhibit various prediction models to act as a tool in determining court decisions with satisfying performance over 70% of overall accuracy. The efficiency of these prediction models was evaluated using k-fold cross-validation, accuracy, sensitivity, specificity, recall, precision, and F-measure. The research is still new, ongoing, and open for exploration. Hence, this is an excellent opportunity for further research concerning the application of machine learning to predicting court decisions. To our knowledge, no studies were conducted to predict the outcome of judicial decisions about alimony cases under Islamic shariah law. Currently, based on the data collected, on average, the alimony judicial process under Shariah law requires one to three years to reach an end in court. A longer time in the judicial process means more money is spent on legal fees. Hence, there is a mounting need to develop a prediction model and act as a tool to expedite the judicial process and decision-making.

This study takes a new look to provide an alternative tool for lawyers and judges in predicting the amount of alimony needed for every child from the father. This amount was determined using machine learning methods based on several factors, such as the salary of the father, the cost of basic needs, and the number of children [6]. Consequently, the judges can determine the proper and reasonable amount of alimony to ensure the children are under protection and care even though their parents were divorced [7]. The significant contribution of this paper is summarized as follows: i) to predict the amount of child alimony using a hybrid fuzzy inference system; and ii) to evaluate the performance of the model using performance metrics. The rest of this paper will discuss the related works and methodology used in this study, followed by the results and performance exhibited by the model, and finally conclude.

2. RELATED WORKS

Fuzzy logic has been widely utilized in the legal field since the late 1980s. Initially, rule-based and dictionary-based models were favored, but more recently, advanced techniques such as decision trees, random forests, natural language processing (NLP), and statistical approaches have shown success in predicting court decisions. Deep neural networks (DNNs) have replaced traditional methods, offering improved performance [8]. The application of machine learning in law primarily aims to enhance efficiency and reduce biases introduced by extraneous factors [9]. Despite the potential for inter-judge disparities in predictions, sentencing guidelines have helped mitigate these discrepancies. However, it's acknowledged that human judgment decisions can be influenced by biases, and when machine learning algorithms are trained on biased data, they can perpetuate these biases. To address this, strategies include collecting more data for underrepresented groups and modifying learning algorithms [10]. Efforts have also been made to neutralize learning biases and increase the transparency and accountability of black box models. There's a growing emphasis on fairness, transparency, accountability, and privacy in the use of machine learning in law [10].

Balkir *et al.* [11] discussed the advantages of using fuzzy logic in law for interpreting complex and ambiguous legal information, filling gaps in legal interpretations, and promoting more equitable legal outcomes. This study believed that fuzzy logic was seen as a valuable tool for understanding multi-valued and variable legal concepts, particularly for legal education, where it can help students comprehend legal realities from different perspectives. Fuzzy logic can be a useful tool in legal education, particularly for young lawyers and law students, in facilitating the interpretation of multi-valued and variable legal concepts. By considering non-contradicting perspectives of legal realities, the use of fuzzy logic in legal education can contribute to achieving more quality and just legal interpretations.

Additionally, Sridevi and Reddy [12] conducted a survey that explored different types of legal expert systems in terms of reasoning, methodologies, and legal domains. It covers rule-based reasoning (RBR), case-based reasoning (CBR), and hybrid systems that integrate RBR and CBR. It also discusses the use of fuzzy logic to handle uncertainty in decision-making processes and the application of neural networks to overcome difficulties in symbolic reasoning systems and facilitate knowledge acquisition. The JUDITH system [13] is a rule-based legal reasoning system that employs rules to construct parts of the German civil code. It is similar to the MYCIN system, a rule-based medical expert system. Thorne [14] is another rule-based reasoner that deals with the taxation of organizations. Split up is a legal expert system that uses if-then rules and neural network theory. Its main functionality is to make predictions about the distribution of marital property following divorce in Australia. These findings highlight the diverse areas where rule-based

expert systems have been successfully deployed in the legal field, as well as the integration of neural networks to enhance their capabilities.

Marandi *et al.* [15] introduced a two-layered fuzzy logic model for predicting court decisions in construction contract disputes. Conducting a questionnaire survey to extract a set of fuzzy rules for identifying important decision parameters and expert knowledge [8]. Proposing a two-layered fuzzy logic-based decision-making architecture for the prediction model. Demonstrating that clauses related to the dissolution and termination of the contract have a significant impact on construction contract disputes. Presenting a proposed hierarchical fuzzy system that can correctly predict nearly 60% of the test data [15]. Establishing a methodology of using arguments before machine learning to establish interpretable AI models. Suggesting that a fuzzy model with a hierarchical structure may be used as a simple and efficient method for predicting court decisions in construction contract disputes.

In summary, fuzzy logic has been extensively applied in legal decision-making processes. The use of fuzzy logic in legal practice, as demonstrated in the papers, is convincing and effective, especially in predicting outcomes in complex legal situations such as the distribution of marital property and construction contract disputes. However, there exists significant untapped potential for the exploration and utilization of fuzzy logic within the realm of Sharia law decision-making. The nuanced and often multifaceted nature of legal interpretations and rulings in Sharia law offers a promising opportunity for the application of fuzzy logic to enhance the precision, fairness, and adaptability of decision-making processes. Further research and experimentation in this domain hold the potential to uncover innovative solutions and insights that could significantly contribute to the field of Islamic jurisprudence.

3. MATERIALS AND METHOD

3.1. Datasets

In this research, datasets were procured from *Bahagian Sokongan Keluarga (BSK)* and *Jabatan Kehakiman Syariah Negeri Johor*. The acquisition of data was officially sanctioned by BSK, demonstrating their keen interest in and endorsement of the research proposal. Based on the Department of Statistics Malaysia (DoSM), there were 623 alimony claims in Johor from 2013 to 2017. However, not all cases that are recorded are successful. Some of the cases are still pending, ongoing, or withdrawn. Hence, only 60 case files have been successfully passed through for 2012, 2014, and 2018, but only 45 case files are ready for analysis, as the rest of the files have incomplete information. From these 45 files, the details have been extracted according to the number of children involved in this alimony allocation. This study focuses on the amount of alimony for each child and manages to have 94 data points for model prediction. The information listed for the process of alimony claims is recorded, and the details are as follows:

- A = Salary of the mother.
- B = Salary of the father.
- C = Number of siblings.
- D = Age of the child.
- E = Amount of alimony allocated for the child.

An attempt was made to search for additional variables needed to determine alimony. In the previous study, there were two main criteria for determining the amount of alimony for children under syariah law: the father's financial capability and the cost of basic needs for each child [16]. However, based on the data obtained, there is little information on the cost of basic needs or justification for the allocated amount because it may differ from the perspective of each judge and may not have accurate or precise information in each case file reviewed. Therefore, the researcher took the initiative to obtain information on the cost of basic needs and living costs from the portal of the Ministry of Economy Malaysia for the years 2010–2018, which was then extracted from the time series of mean monthly household consumption expenditure in Malaysia from 1993–2019 [17], and the information is tabulated in Table 1.

Table 1. Mean monthly household expenditure in Malaysia

Group	2010 (MYR)	2012 (MYR)	2014 (MYR)
Food	444	676	726
Clothing	75	124	136
Education	31	41	54
Total	550	841	1,005

3.2. Method

This section will discuss the components of the fuzzy rule-based system (FRBS). The FRBS system has five components: input variables, linguistic sets, membership functions, fuzzy rules, and defuzzification.

These components work together to process input data, apply fuzzy logic, and generate a crisp output in terms of value. This study proposed a hybrid fuzzy system that combines elements of both Mamdani and Takagi-Sugeno-Kang (TSK) fuzzy systems, as it involves defuzzification to obtain a crisp output value instead of linguistic labels. In a pure Mamdani fuzzy system, the output is represented as linguistic labels (e.g., “low,” “medium,” “high”). On the other hand, a TSK fuzzy system provides a more precise output that directly gives the numeric value as the result of the inference [18]. This study is designed with a Mamdani-like structure, providing linguistic labels for the antecedents and consequents. However, the output variable and its universe of discourse are defined as numeric, indicating a TSK-like behavior with crisp numeric outputs. This study incorporates a method to predict the amount of a child’s alimony based on the input variables determined by expert knowledge. Each fuzzy membership function captured the linguistic terms associated with each variable and described the relationship between the input variables and the amount of the child’s alimony.

3.2.1. Selection of input and output variables

The second step aims to define input-output variables, whereby the output variable describes the possible outcomes of the decision and the input variables define the possible value that it could take. Defining input-output variables is a pivotal step in constructing a predictive model for child alimony. The output variable, representing the amount of child alimony, serves as the focal point of the model, encapsulating the ultimate decision to be predicted. Conversely, the input variables encompass a range of factors that influence this decision, such as the income of the father, children’s needs, and the number of children involved. Through input-output analysis, the intricate relationships between these variables are elucidated, revealing how they collectively contribute to determining the predicted amount of child alimony. By understanding these linkages, the predictive model can effectively translate input data into meaningful predictions, aiding in the fair and accurate determination of child alimony amounts in Syariah Courts.

3.2.2. Determination of linguistic sets

Fuzzy logic deals with linguistic variables, which come from expert opinions [19]. These linguistic sets define the membership functions for each variable in the FRBS. The ranges specified for each linguistic set determine the boundaries and shapes of the triangular membership functions used to represent the fuzzy sets. By associating the input values (salary of the father, number of children, and cost of basic needs for the child) and the output value (amount of the child’s alimony) with these linguistic sets and evaluating the fuzzy rules, the system performs fuzzy inference to determine the degree of membership of the output variable in each linguistic set. The final crisp output value is obtained through defuzzification based on the aggregated membership values.

According to the judge’s assessment, they will decide the amount of the child’s alimony based on four factors, including the father’s socioeconomic status, the father’s highest ability, the market price of basic necessities, and the child’s sufficiency [20]. However, some of the judges think that it is appropriate to set a reasonable value and follow the minimum criteria to reduce the father’s burden [21]. Based on the 2019 amenities survey report, the income classification for the B40 household group can be divided into four categories: B1 (less than RM2500), B2 (RM2500-RM3169), B3 (RM3170-RM3969), and B4 (RM3970-RM4849) [22]. By referring to the collected data, the highest income is RM4000; hence, the linguistic variables and values in this study consist of three sets, which are low (L), medium (M), and high (H) for all input and output variables.

3.2.3. Construction of the fuzzy membership functions

Both input and output variables from linguistic expression are needed to determine their fuzzy character, as parameterized membership functions are associated with the predefined value of a linguistic term for each variable. Each membership function describes an expert; thus, to obtain appropriate numerical values This study produced these values from data collection and human experts [23]. The trapezoidal function is used for this study as it allows more complex and asymmetrical relationships between input values and linguistic terms. The trapezoidal membership function $f(x)$ is defined by specifying four parameters a , b , c , and d , where a and d control the left and right feet or base points of the trapezoid. The parameters b and c control the left and right shoulders, or top points, of the trapezoid.

3.2.4. IF-THEN rules

The “if-then” rules, also known as fuzzy rules, define the logical relationships between the input variables and the output variables in a FRBS. They capture expert knowledge or heuristics about how the inputs affect the output. Each rule consists of an antecedent (conditions), which is denoted as IF, a consequent (conclusion), which is denoted as THEN, and the connective AND, which indicates the

relations between the antecedents. In this study, let the salary of the father, the number of children, the cost of basic needs, and the amount of the child’s alimony be the fuzzy sets A, B, C, and O, respectively. Using tree diagram rules, since there are 3 variables and 3 linguistic sets, it will contribute to 27 rule statements that will be as follows:

- IF A is low AND B is low AND C is low THEN O is medium
- IF A is low AND B is low AND C is medium THEN O is medium
- IF A is low AND B is low AND C is high THEN O is medium
- IF A is low AND B is medium AND C is low THEN O is low
- IF A is low AND B is medium AND C is medium THEN O is medium
- IF A is low AND B is medium AND C is high THEN O is medium
- IF A is low AND B is high AND C is low THEN O is low
- IF A is low AND B is high AND C is medium THEN O is medium
- IF A is low AND B is high AND C is high THEN O is medium
- IF A is medium AND B is low AND C is low THEN O is medium
- IF A is medium AND B is low AND C is medium THEN O is medium
- IF A is medium AND B is low AND C is high THEN O is medium
- IF A is medium AND B is medium AND C is low THEN O is medium
- IF A is medium AND B is medium AND C is medium THEN O is medium
- IF A is medium AND B is medium AND C is high THEN O is medium
- IF A is medium AND B is high AND C is low THEN O is low
- IF A is medium AND B is high AND C is medium THEN O is medium
- IF A is medium AND B is high AND C is high THEN O is medium
- IF A is high AND B is low AND C is low THEN O is medium
- IF A is high AND B is low AND C is medium THEN O is high
- IF A is high AND B is low AND C is high THEN O is high
- IF A is high AND B is medium AND C is low THEN O is medium
- IF A is high AND B is medium AND C is medium THEN O is high
- IF A is high AND B is medium AND C is high THEN O is high
- IF A is high AND B is high AND C is low THEN O is medium
- IF A is high AND B is high AND C is medium THEN O is medium
- IF A is high AND B is high AND C is high THEN O is medium

The ranges for each variable’s linguistic values are based on the data collected and recorded in Table 2. Expert guidance was sought in this study to rationalize the parameters and regulations, aligning them with the prevailing conditions observed in the studied data [24]. This includes the consequent, which was determined from the expert’s opinion, where it must meet the minimum value that will not burden the fathers and at the same time fulfill the minimum requirements of the children [25].

Table 2. The variable range

Linguistic values	Father’s ability, A	Number of children, B	Cost of basic needs, C
Low (L)	[0, 2,500]	[1, 2]	[0,600]
Medium (M)	[2,500, 3,100]	[3, 4]	[600,900]
High (H)	[3,100, 4,000]	[5, 6]	[900,1,500]

3.2.5. Defuzzification

After aggregation, which is the process of combining the individual input values into a single output, defuzzification will convert the aggregated fuzzy set into a single crisp value. In this process, this study integrated elements of both Mamdani and TSK fuzzy logic approaches. Initially, the TSK model is used to calculate a real-valued output, which represents a continuous estimate based on the fuzzy rules and input values. In this study, centroid defuzzification returns the center of gravity of the fuzzy set along the x-axis. If you think of the area as a plate with uniform thickness and density, the centroid is the point along the x-axis about which the fuzzy set would balance. The centroid is computed using the following formula as in (1), where $\mu(x_i)$ is the membership value for point x_i in the universe of discourse.

$$\frac{\sum_i \mu(x_i)x_i}{\sum_i \mu(x_i)} \tag{1}$$

However, to align the final output with practical data requirements and ensure its usability, a post-processing step is applied. This step involves rounding the real-valued output to the nearest multiple of 50, resulting in a crisp (single-valued) output. This hybrid approach combines the interpretability and classification capabilities of the Mamdani system with the flexibility and precision of the TSK system while ensuring that the output conforms to the specific constraints or units relevant to the real-world application.

4. RESULTS AND DISCUSSION

The performance of the proposed FRBS is measured using performance metrics that analyze accuracy, precision, recall, and F1-score. A comparison performance for two types of membership functions: triangular and trapezoidal, was recorded and presented in Table 3. Based on the results in Table 3, it can be concluded that the trapezoidal membership function has higher accuracy compared to the triangular membership function, which is 0.69, which means that 69% of the predictions are correct. The precision of the model is 0.70, which indicates that when the model predicts a positive class, it is correct 70% of the time. The recall (also known as sensitivity or true positive rate) of the model is 0.75, which means that the model correctly identifies 75% of the positive instances. The F1-score of the model is 0.69, which is the harmonic mean of precision and recall. It balances both metrics and is useful when there is an imbalance between the classes.

Out of the 94 data points that have been predicted, four case studies were extracted for misfit classification and presented in Table 4. According to the above table, in case no. 10, with the father's salary of RM2500 and three children, the judges decided the amount of alimony for the child is RM100. Meanwhile, case no. 38 had the same information, but the judges decided the amount was RM200. However, the prediction model gives the same value for both cases as the information is the same, which is RM200. This shows that the prediction model can reduce bias and standardization in decision-making. For case no. 5, the father's salary is RM2400, and the judge's decision for the alimony is RM100. Compared to case no. 8, the salary is lower than case no. 5, which is RM1000, but he needs to pay a higher amount of alimony, which is RM150. This may lead to unfairness in decision-making.

Based on the result in Figure 1, the model's accuracy is 69%, which can be considered a getargeting point and can be improved. The previous study by Nasohah [20] mentioned that judges understand that the maintenance assessment should be based on sufficiency and ma'rif criteria, as fuqaha discussed. However, in practice, sufficiency needs to be more transparent in the judgment process, with some cases prioritizing court procedures over the basic needs of the party seeking maintenance. There is a law that needs more coordination among judges in determining the essential and current items in maintenance and assessing the societal practices and prices of goods.

Table 3. Performance metric

	Triangular MF	Trapezoidal MF
Accuracy	0.66	0.69
Precision	0.66	0.70
Recall	0.68	0.75
F1-Score	0.65	0.69

Table 4. Misfit classification

Case No	Variables/Input	Judge's decision	Predicted value
5	A = 2,400 B = 3 C = 550	100	200
8	A = 1,000 B = 2 C = 550	150	100
10	A = 2,500 B = 3 C = 550	100	200
38	A = 2,500 B = 3 C = 550	200	200

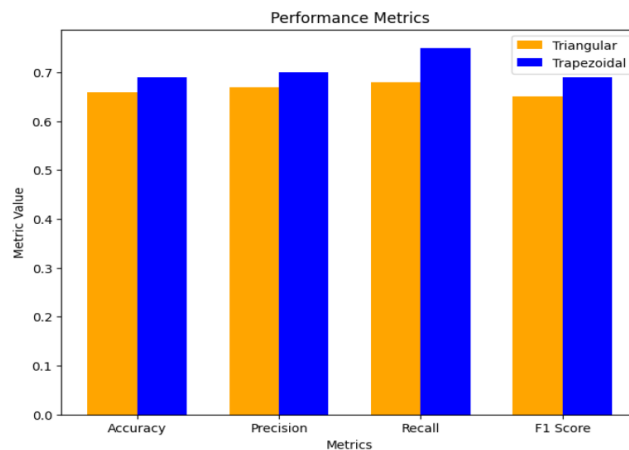


Figure 1. Performance metric's result of triangular and trapezoidal membership function

Further support [21] suggests that the court's consideration of the form of maintenance has changed over time. The main categories of alimony are food, clothing, education, medical expenses, and expenses for celebrating festivals. However, some judges think medical expenses can be waived as the mother can send the children to the government hospital rather than in the main categories under the father's responsibilities [24]. The expenses for celebrating festivals have been recognized as part of maintenance since the 1990s. As such, the court may order the father to pay for the children's expenses for celebrating festivals [25].

The research findings help family law and child welfare policymakers and agencies. The trapezoidal membership function predicted child alimony better than the triangular membership function (69%). The model's positive class prediction accuracy is confirmed by precision, recall, and F1-score. Identifying misfit classifications shows the model's potential to reduce bias and standardization in judicial decision-making. For instance, cases with similar information but different judicial decisions show how the model can promote consistency in alimony assessments, promoting legal fairness. The study emphasizes transparency in sufficiency judgments and advises policymakers to prioritize maintenance seekers' essential needs over procedural issues. Coordination among judges is essential for determining essential and current maintenance items that align with social and economic factors. Additionally, changing maintenance categories require legal adaptation. The 1990s recognition of festivals as maintenance suggests a dynamic legal landscape that requires ongoing assessment and legislative changes. To make the model more applicable, future policy should validate the cost of basic needs, taking judges' perspectives into account. Defuzzification improvements and aggregating multiple sub-inputs into one variable may improve the prediction model.

In general, prior studies show that determining the cost of basic needs might differ from the judge's view. Since the judges might consider different items in determining the cost of basic needs for the child, the researcher might validate this model using current data and information. Further study might consider advancing the defuzzification method to increase accuracy and aggregating multiple sub-inputs into a single input variable and sub-input information into the prediction model.

5. CONCLUSION

Our study presents a new predictive tool called the FRBS for estimating child alimony under syariah law. The FRBS achieves an impressive accuracy of 69%, which is higher than the accuracy of 66% achieved with a triangular membership function. The utilization of a trapezoidal membership function demonstrated its superiority. To optimize this methodology, we propose the integration of heterogeneous sub-inputs and the consolidation of diverse input variables into a unified internal input for the FRBS. This adaptability takes into account the varied viewpoints of judges, recognizing the possibility of fluctuations in variables over a period of time. The ability to adapt input data modeling to specific scenarios is advantageous as it aligns with judicial preferences and facilitates nuanced decision-making. This study highlights the possibility of consistently improving and enhancing our suggested model, with a focus on its ability to adjust to changing legal situations. The results of our research represent a notable advancement in utilizing machine learning applications in the legal field, aiding in the effective calculation of child alimony and ensuring fairness in accordance with Islamic syariah law. The outcomes derived from this research provide practical and implementable knowledge for policymakers, advocating for a holistic approach to the field of family law and the evaluation of alimony. The study promotes the importance of transparency, consistency, and continuous adaptation in legal procedures to safeguard the welfare of children involved in divorce proceedings within the framework of Islamic syariah law.

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