International Journal of Innovative
Computing, Information and Control
Volume **20**, Number **5**, October **2024**

ICIC International ©2024 ISSN 1349-4198
pp. **1463–1477**

THE FUZZY RULE BASED SYSTEM FOR DETERMINING THE LEVEL OF HADITH *SANAD* AUTHENTICATION STATUS

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Received September 2023; revised January 2024

Abstract. *Hadith is the second primary reference after Holy Qur'an for more than 1.8 billion Muslims worldwide. Internet and social media provide many al-Hadith sources. Unfortunately, this variety exposes Muslims to both real and fake Hadiths, making false Hadiths more popular than ever. The current systems for authenticating Hadith require detailed input, but the output does not indicate the level or category of the Hadith as defined by Hadith Science. This study proposes a Hadith Sanad Authentication Fuzzy Expert System (HAFES) that enhances knowledge acquisition and a fuzzy membership-determination approach for an expert system that can track the Hadith Sanad in determining the level of the Hadith. The result displayed that the HAFES performs well. The fuzzy inference model for the Tsiqah Level got an accuracy value of 92.72%, a precision of 98.12%, and a recall of 98.12%. The fuzzy inference model for Missing Narrators Level got an accuracy value of 98.16%, a precision of 97.16%, and a recall of 97.10%. Moreover, the final fuzzy inference model for Hadith Sanad Status Level got an accuracy value of 72.2%, a precision of 66.2%, and a recall of 76.9%.*

Keywords: Hadith, *Sanad*, Authentication, Fuzzy Expert System, Fuzzy knowledge acquisition, Fuzzy membership function determination

1. **Introduction.** Islam's global presence is extensive, with more than 1.88 billion individuals following the faith in 2023, equivalent to roughly 23.33% of the global population [1]. Indonesia boasts the largest Muslim population worldwide, with over 229 million Muslims constituting 82.51% of the country's total population in 2023, or 12.21% of the global Muslim population [1]. The Qur'an and Hadith hold paramount importance in the Islamic belief system, serving as foundational sources for Islamic teachings [2]. The Holy Qur'an is a divine revelation, a universal message from Allah, while the Hadith provides valuable insights into the life and teachings of Prophet Muhammad (PBUH) [3].

In the era of the Internet and social media, a wide range of sources for al-Hadith are available. However, unfortunately, this variety exposes Muslims to both genuine and fabricated Hadiths, making the threat of false Hadiths more prevalent than ever [4]. The Internet has become a platform where numerous false Hadiths are circulated by unscrupulous individuals, leading to challenges in discerning between authentic and fabricated Hadiths for Muslims and non-Muslims interested in Hadiths [4,5]. Unlike conventional information dissemination channels, the Internet lacks comprehensive rules and regulations governing

DOI: 10.24507/ijicic.20.05.1463

the publication of information, resulting in limited control over content creators and how data is presented. Thus, it becomes necessary to critically examine the authenticity and originality of Hadiths obtained from the Internet [5].

The classification of Hadith defined in Hadith Science is the foundation for the framework used to authenticate them. The authentication level of a Hadith can be determined by evaluating the condition of its components: the *Matn* (the text of the Hadith) and the *Sanad* (the chain of narrators who transmit the Hadith text) [2]. Most previous studies authenticating Hadith *Matn* were conducted manually by Hadith domain experts [6]. Several researchers employed machine learning to authenticate Hadith *Sanad*. Most of these studies required predefined input values, and most Hadith Authentication outputs are *Sahih* or *Da'if* only [7-12]. This study aims to address the challenges of authenticating Hadith *Sanad*. It is the first step in automatic authentication and can be continued with *Matn* Authentication. Currently, Hadith *Matn* Authentication is done manually by Hadith experts and beyond the scope of this research.

Based on the above elaboration, the primary analysis of current research on the Hadith *Sanad* Authentication method is as follows: 1) Existing Hadith Authentication systems require the input to be complete for authentication. Otherwise, it is not possible; 2) The output of existing Hadith *Sanad* Authentication systems lacks emphasis on the level or category of Hadith defined by Hadith Science. This study aims to address the challenges mentioned earlier. Specifically, it has two focuses on 1) To develop a knowledge acquisition approach of the Hadith Authentication Expert System that integrates a wide range of natural language Hadith text with experts' input; 2) To develop a fuzzy expert system that is able to track the Hadith *Sanad* in determining the level of the Hadith. The focus of this study has two contributions: 1) An enhanced knowledge acquisition approach that systematically integrates a wide range of natural language input with human expert knowledge into a knowledge base; 2) A fuzzy membership-determination approach for an expert system that is able to track the Hadith *Sanad* in determining the level of the Hadith.

The subsequent sections of this paper are structured as follows. Section 2 provides an extensive review of the existing literature. Section 3 introduces the proposed model, Hadith *Sanad* Authentication Fuzzy Expert System (HAFES). Section 4 presents a comprehensive description of the results and evaluation of HAFES. Finally, Section 5 concludes the paper by presenting key findings and implications.

2. **Literature Review.**

This study focuses on enhancing the knowledge acquisition and fuzzy membership-determination approaches for the Hadith *Sanad* Authentication Expert Systems. This section describes studies on Hadith *Sanad* Authentication and methods or approaches for membership function determination.

2.1. **Hadith *Sanad* Authentication.**

Table 1 compiles various research studies conducted on the Hadith *Sanad* Authentication. Each study's input, methodology, output, and evaluation criteria are meticulously detailed, providing a comprehensive overview of prior investigations in this field.

As shown in Table 1, for examining the authenticity of Hadith using *Sanad*, several works have utilized machine learning method [3,7-9,11,12,14,15], and some have exploited rule-based expert system [10], and others using an ontology rule-based paradigm [13].

2.2. **Methods or approaches for membership function determination.**

The fuzzy Membership Function (MF) is a fundamental concept in fuzzy system design. For the results to be reliable, the MF must be defined correctly and precisely [16]. Expert Systems' MFs are typically designed through trial and error and rely on expert knowledge

TABLE 1. Current studies on Hadith *Sanad* Authentication

Citation	Input	Method	Output	Evaluation metric
[7]	445 data of Chain of Narrators	Applying machine learning algorithm Naïve Bayes and Vector Space Model (VSM)	Status of Hadith Authentication into Maqbul and Mardud	Accuracy: 97%, 55%, 50% on 100, 20, 10 data testing
[8]	160 Hadith Text with manual preprocessing	Vector Space Model (VSM) and Learning Vector Quantization (LVQ)	Hadith Authentication into *Sahih*, *Hasan*, Da'if and Maudhu'	Precision: Average 50%
[3]	Hadith Text	Takhrij Hadith using a Unicode centric string-matching approach	Hadith Authentication into *Sahih*, *Hasan*, Da'if	N/A
[9]	Hadith Isnad	Hadith Science combined with Associative Classification (AC)	Hadith Authentication into *Sahih* and Da'if	N/A
[10]	Pre-defined value of narrator's status, Marfû' word	Rule-based Expert System	Hadith Class	N/A
[11]	Pre-defined value of Hadith Features	Takhrij Hadith combined with Decision Tree (DT) classifier and Missing Data Detector (MDD)	Hadith Authentication into *Sahih*, *Hasan*, Da'if and Maudhu'	- Correct Classification Rate 97.597% - Sensitivity 97.6% - Specificity 99.4% - Receiver Operating Characteristic Curve 0.996
[12]	Pre-defined value of Hadith Features	Decision Tree (DT) and Naïve Bayes Classifier with Missing Data Detector	Hadith Authentication into *Sahih*, *Hasan*, Da'if and Maudhu'	DT Classifier - Correct Classification Rate 97.597% - Sensitivity 97.6% - Specificity 99.4% - Receiver Operating Characteristic Curve 0.996 NB Classifier - Correct Classification Rate 96.6967%
[13]	Hadith Isnad	Ontology and Ontology Reasoning (rule-based)	Isnad authentication and Hadith Authentication	Accuracy and User Acceptance Test/Hadith Specialist 81%

TABLE 2. Methods or approaches on FES membership function determination

Citation	Domain	Methods/approaches
[17]	Variable Speed Refrigeration System	Systematic MF Design
[18]	N/A	MF construction utilizing the middle hedge operator
[19]	Partial Nitritation/Anammox system	Systematic MF Design
[20]	Plastic Injection Molding Processes	Adaptive MF based on defect behavior
[21]	Heat Exchange Process	Experiments-based MF optimization
[22]	Molten Salt Breeder Reactor (MSBR) Control	MF optimization utilizing NDAC-CTO method
[23]	Early Diagnosis of Breast Cancer	MF construction utilizing Fuzzy Neural Network

[17]. Furthermore, several studies proposed a novel approach to Fuzzy Expert System MF determination. Table 2 presents previous studies on the formulation of MF for Fuzzy Expert Systems.

Based on the table, some of the authors [17,19] conducted a systematic MF Design. Chaves et al. proposed the adaptive MF Generation [20]. Several works proposed the automatic MF Generation [18,23]. Apart from that, there are also several existing works on membership function optimization [21,22].

The previous research for authenticating Hadith based on *Sanad* shows that according to input parameters, methods, and output, most input was manually pre-processed to get the involved narrators. In this case, the complete Hadith text is needed in the *Sanad* section so that verification can be carried out. In the output section, most of it only defines the status of Hadith in Maqbul-Mardud, Sahih-Da'if, and Sahih-Hasan-Da'if-Maudhu-Mauquf. This does not fully explain the status of Hadith *Sanad* based on Hadith Science. For the Fuzzy Expert System, prior studies highlight diverse approaches to knowledge acquisition in various domains, including agriculture, medicine, industrial safety, decision-making, risk assessment, and corrosion analysis. While each study offers unique insights and methodologies for knowledge acquisition and membership function determination, several commonalities and differences are worth considering.

This study proposed a model capable of accepting incomplete Hadith text input, pre-processing it for authentication, and automatically identifying the Hadith Narrator from the natural Hadith text. Then, the wide range of Hadith text in a natural language and the expert input were systematically integrated into the knowledge acquisition process so that the knowledge base could be utilized for the Hadith Authentication process. Ultimately, the output model of Hadith Authentication improved to classify Hadith based on Hadith Science.

3. The Framework of Hadith *Sanad* Authentication Fuzzy Expert System (HAFES).

The framework of HAFES is shown in Figure 1.

Figure 1 demonstrates that the HAFES acquires knowledge from the output of the natural language text extraction model and the domain expert. The natural text extraction approach consists of two parts. The proposed similarity model is the first. Since the input text can only be processed if it is complete, this section is an engine that converts the frequently incomplete raw text Hadith input into a complete text Hadith. The proposed similarity model uses BERT and LSTM to determine text similarity [25]. The proposed named entity recognition is the second part. As previously stated, Hadith *Sanad*'s status

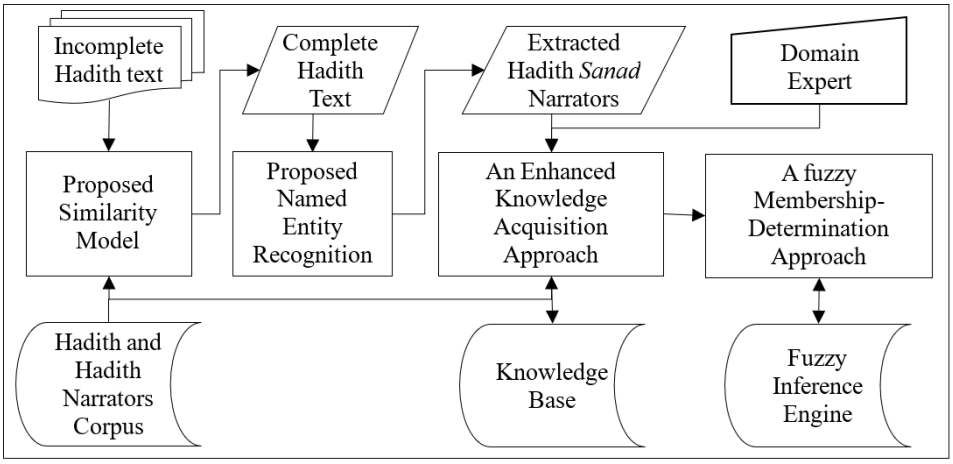

FIGURE 1. Design of HAFES knowledge acquisition and membership function determination

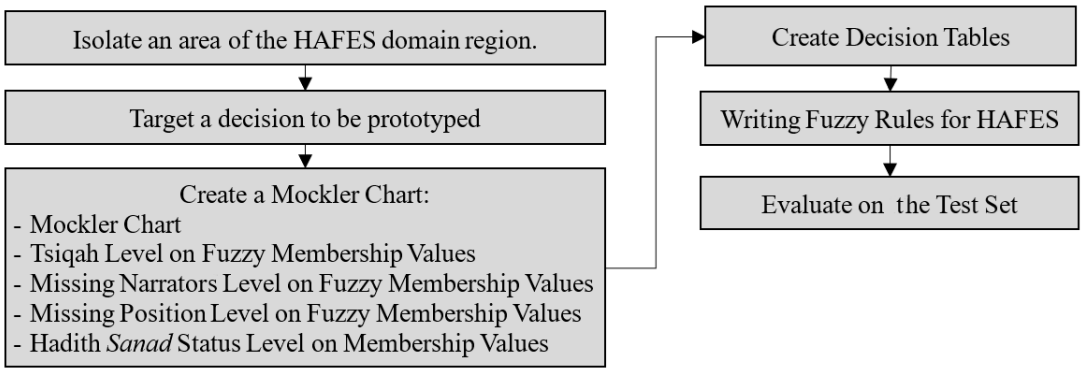

FIGURE 2. Methodology for HAFES knowledge acquisition, membership function, and fuzzy rules determination

is determined by two factors. The first factor is the state of the narrators who took part in Hadith *Sanad*, and the second is the structure of a narrator chain. Therefore, taking the narrator out of the Hadith text is crucial. This process uses a modified version of BERT to conduct NER to identify the narrator's name [26].

Figure 2 shows a compilation of the methodological strategy for investigating the HAFES knowledge acquisition, membership function, and fuzzy rules determination.

3.1. **Isolate the HAFES domain region.** The HAFES is constructed to determine the Hadith Authentication Level, and the method must determine a Hadith's authenticity based on its *Sanad* and *Matn*. The HAFES focuses on the Hadith *Sanad* Authentication to align with the objective of this research: to develop a Fuzzy Expert System that can track the Hadith *Sanad* in assessing the level of the Hadith.

3.2. **Identify a prototype decision.** In the phase of isolating the HAFES domain region, the discussion has been narrowed to focus on *Sanad* Authentication. The next stage is to identify the target a decision to be prototyped. This phase consists of two steps: 1) Construct a block diagram of the target, and 2) Define the factors involved. This phase aims to get a detailed description of all factors influencing the target's decision and its relation. According to the literature known that the *Sanad* Authentication requirement, the following components must be present for a Hadith to be considered authentic:

1) All Hadith *Sanad* narrators were *'Adil* (trustworthiness).

2) All Hadith *Sanad* narrators were *Dhabith* (has a strong memory).
3) The Hadith *Sanad* is unbroken.

The parameters *'Adil* and *Dhabith* can be merged using the term *Tsiqah*. The narrator with the status *'Adil* and *Dhabith* can be given the status *Tsiqah*. Otherwise, the narrator that is not *'Adil* and is not *Dhabith* cannot be given the status *Tsiqah*. The unbroken Hadith *Sanad* and its level can be judged using 1) the number of Missing Narrators and 2) the position where the Missing Narrators exist in the chain of narrators. Based on that analysis, then it defined in this phase:

1) The target is *Sanad* Authentication.
2) The factors involved are *Tsiqah* Level, Missing Narrators Level, and Missing Narrators Position.

3.3. **Assemble a Mockler Chart.** The Mockler Chart will illustrate the relationship between the variables that affect the target and the questions, guidelines, and recommendations provided. Not all *Sanad* Authentication status is used. Figure 3 presents the Mockler Chart for the HAFES.

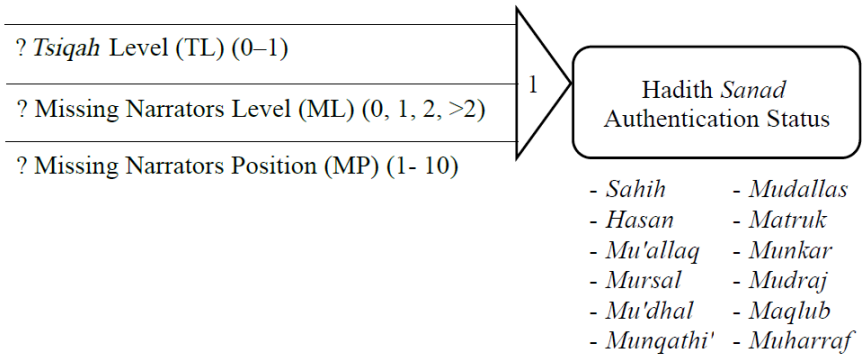

FIGURE 3. Mockler Chart for the HAFES

Based on the Mockler Chart and additional analysis of the status definition, the HAFES output is mapped depending on the provided inputs, as arranged in Table 3.

3.3.1. *Tsiqah Level.* It is essential to develop a paradigm for determining the *Tsiqah* Level of each category. The initial values on each factor in Table 3 were still not defined since it was given from the abstraction of the definition of each *Sanad* status. As shown in Figure 4, the fuzzy membership function was proposed to define the level of *Tsiqah*. The fuzzy is suitable for defining the level of *Tsiqah* since fuzzy membership function can give the abstraction for the level of *Tsiqah*.

Four scenarios were utilized to complete the first through fifth steps. These four scenarios are used to get the comparison condition between four categories of level *Tsiqah*. The difference between each scenario: 1) The samples of *Sahih* Hadith are used in Scenario 1; 2) Scenario 2 employs Hadith samples with the status of *Hasan*; 3) Scenario 3 employs Hadith samples with the quality of *Matruk* and *Munkar*; and 4) Scenario 4 engages Hadith samples with groups other than *Sahih*, *Hasan*, *Matruk* and *Munkar*.

Steps one through three from the methodology in Figure 4 were conducted for each of the four scenarios. And the result is described as follows:

- Scenario 1

  2,165 Hadith *Sahih* from Tirmidzi Book, 1,857 Unique Hadith Narrators and 12,752 Combination Narrator – Hadith (*Kutubus Sittah*).

Table 3. The HAFES input output mapping

Rules	Input			Output	Description
	Missing Narrators Level (ML)	Missing Narrators Position (MP)	*Tsiqah* Level (TL)		
R1	0	0	All	*Sahih*	*Hadith*, to which all *Sanad* is connected, all narrators *Tsiqah*.
R2	0	0	All but the level lower than *Sahih*	*Hasan*	*Hadith*, to which all *Sanad* is connected, all narrators *Tsiqah*, but the level is not like *Sahih*.
R3	>= 1	All narrators except the *Shahabat* or *Shahabat* and *Tabi'in* together	All but the level lower than *Sahih* and *Hasan*	*Mu'allaq*	*Hadith*, to which all levels can have Missing Narrators except companion or companion and *Tabi'in* levels together.
R4	1	After *Shahabat* or *Tabi'in*	All but the level lower than *Sahih* and *Hasan*	*Mursal*	*Hadith*, which is possibly Missing Narrators after the companion or *Tabi'in*.
R5	>= 2	*Shahabat* and *Tabi'in*, in that order, or *Tabi'in* and *Tabi'in Tabi'in*, or after	All but the level lower than *Sahih* and *Hasan*	*Mu'dhal*	*Hadith* might have a series of Missing Narrators on the companion and *Tabi'in*, *Tabi'in*, and *Tabi'in Tabi'in*, or after that.
R6	>= 1	Anywhere, not in order	All but the level lower than *Sahih* and *Hasan*	*Munqathi'*	*Hadith* might have more than one Missing Narrators on all levels, but not in sequence.
R7	0	0	Exist >=1 Narrators not *Tsiqah*	*Matruk*	*Hadith* might have narrators who are accused of lying.
				Munkar	*Hadith* might have narrators who are accused of forgetfulness.
R8	0	0	All but the level lower than *Sahih* and *Hasan*	*Mudraj*	Inserting a narrator who should not be in the Hadith chain (*Sanad*).
				Maqlub	Replace the narrator's name with his father's.
				Muharraf	There is a difference of 1 letter (*syakal*) in the *Sanad*.

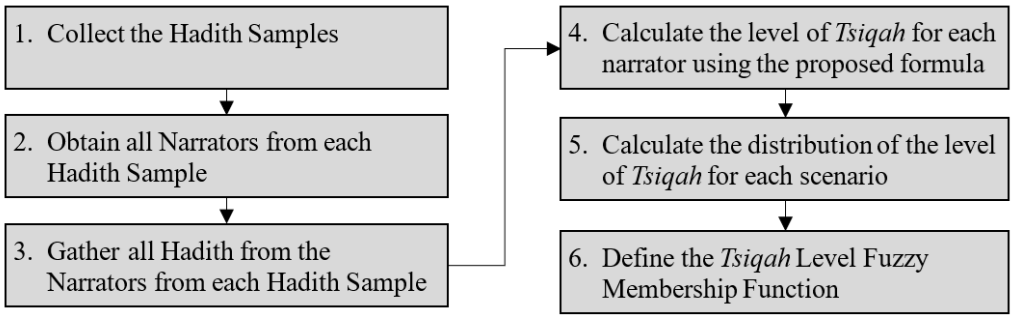

FIGURE 4. Methodology for determining fuzzy membership function of the *Tsiqah* Level

- Scenario 2
  353 Hadith *Hasan* from Tirmidzi Book, 771 Unique Hadith Narrators, and 2,074 Combination Narrator – Hadith (*Kutubus Sittah*).
- Scenario 3
  12 Hadith *Matruk* or *Munkar* from Tirmidzi Book, 69 Unique Hadith Narrators, and 73 Combination Narrator – Hadith (*Kutubus Sittah*).
- Scenario 4
  517 Hadith with another status than *Sahih*, *Hasan*, *Matruk* and *Munkar* from Tirmidzi Book, 1,174 Unique Hadith Narrators, and 3,107 Combination Narrator – Hadith (*Kutubus Sittah*).

In the third step from the methodology in Figure 4, the proposed formula is used to determine the level of *Tsiqah* for each narrator. The formula equation is proposed for each level of *Tsiqah*.

$$TS = \left(\frac{\sum_{i=0}^{n(A)} a_i + \cdots + a_{n(A)}}{\sum_{i=0}^{n(X)} x_i + \cdots + x_{n(X)}} \right) \times 100\% \tag{1}$$

$$TH = \left(\frac{\sum_{i=0}^{n(B)} a_i + \cdots + a_{n(B)}}{\sum_{i=0}^{n(X)} x_i + \cdots + x_{n(X)}} \right) \times 100\% \tag{2}$$

$$TMM = \left(\frac{\sum_{i=0}^{n(C)} a_i + \cdots + a_{n(C)}}{\sum_{i=0}^{n(X)} x_i + \cdots + x_{n(X)}} \right) \times 100\% \tag{3}$$

$$TO = \left(\frac{\sum_{i=0}^{n(D)} a_i + \cdots + a_{n(D)}}{\sum_{i=0}^{n(X)} x_i + \cdots + x_{n(X)}} \right) \times 100\% \tag{4}$$

TS refers to the level of *Tsiqah Sahih*. *TH* refers to the level of *Tsiqah Hasan*. *TMM* refers to level of *Tsiqah Matruk* or *Munkar*. *TO* refers to level of *Tsiqah* Others (Hadith with another status than *Sahih*, *Hasan*, *Matruk* and *Munkar*). $X = \{x | x \text{ is All Used Hadith Samples}\}$. $A = \{a | a \text{ is } Sahih, a \in X\}$. $B = \{b | b \text{ is } Hasan, b \in X\}$. $C = \{c | c \text{ is } Matruk/Munkar, c \in X\}$. $D = \{d | d \text{ is Others Status}, d \in X\}$. $n(X) = |X|$, the cardinality of X. $n(A) = |A|$, the cardinality of A. $n(B) = |B|$, the cardinality of B. $n(C) = |C|$, the cardinality of C. $n(D) = |D|$, the cardinality of D.

Then the fifth step, calculating the distribution of the level of *Tsiqah* for each scenario, was conducted with the formula below.

$$NS_{in\ range} = \frac{|TS_{in\ range}|}{|X|} \times 100\% \tag{5}$$

$$NH_{in\ range} = \frac{|TH_{in\ range}|}{|X|} \times 100\% \tag{6}$$

$$NMM_{in\ range} = \frac{|TMM_{in\ range}|}{|X|} \times 100\% \tag{7}$$

$$NO_{in\ range} = \frac{|TO_{in\ range}|}{|X|} \times 100\% \tag{8}$$

$NS_{in\ range}$ refers to the distribution of TS in the values range. $NH_{in\ range}$ refers to the distribution of TH in the values range. $NMM_{in\ range}$ refers to the distribution of TMM in the values range. $NO_{in\ range}$ refers to the distribution of TD in the values range. The values range is set for each 10% increment level with all values range is 0-100%. Table 4 shows an example of the distribution of *Tsiqah* Level calculations.

Table 4. Distribution of *Tsiqah* Level example

Values range	Cardinality of				Percentage of			
	$TS_{in\ range}$	$TH_{in\ range}$	$TMM_{in\ range}$	$TO_{in\ range}$	$NS_{in\ range}$	$NH_{in\ range}$	$NMM_{in\ range}$	$NO_{in\ range}$
90-100	126	–	–	–	5.8%	0.0%	0.0%	0.0%
80-89	1,341	–	–	–	61.9%	0.0%	0.0%	0.0%
70-79	518	–	–	–	23.9%	0.0%	0.0%	0.0%
60-69	139	–	–	–	6.5%	0.0%	0.0%	0.0%
50-59	31	1	–	–	1.4%	0.0%	0.0%	0.0%
40-49	8	4	–	1	0.4%	0.2%	0.0%	0.0%
30-39	2	13	–	7	0.1%	0.6%	0.0%	0.3%
20-29	–	76	–	115	0.0%	3.5%	0.0%	5.4%
10-19	–	426	1	931	0.0%	19.7%	0.0%	43.0%
0-9	–	1,645	2,164	1,111	0.0%	76.0%	100.0%	51.3%
$\|X\|$	2,165	2,165	2,165	2,165	100%	100%	100%	100%

The final step is to define the fuzzy inference model for *Tsiqah* Level and its membership function. Figure 5 shows fuzzy inference system results for the *Tsiqah* Level.

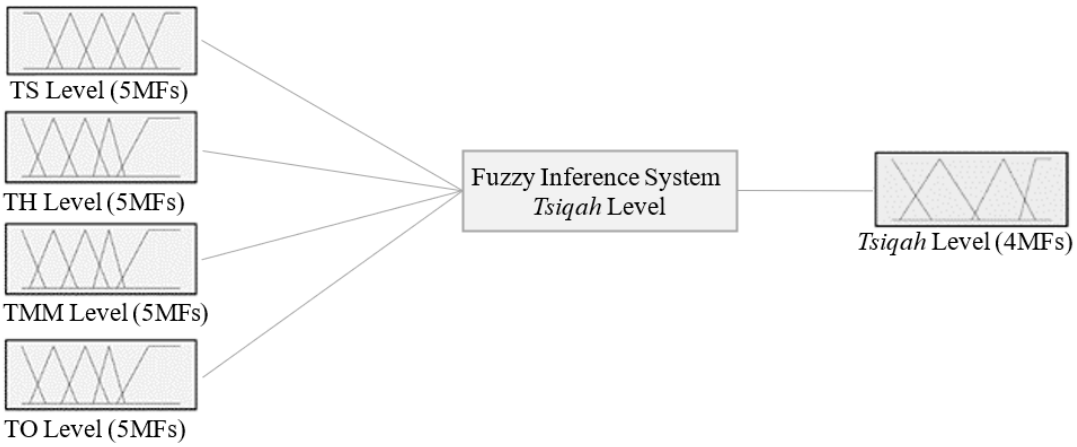

Figure 5. Fuzzy inference system for the *Tsiqah* Level

3.3.2. *Missing Narrators Level.* After defining *Tsiqah* Level, it needs to define the Missing Narrators Level for the Hadith status of *Mu'allaq*, *Mursal*, *Mu'dhal*, and *Munqathi'*. Missing Narrators and Missing Narrators Position are set to different values. Details are as follows:

- *Tsiqah* Level = All but the level lower than *Sahih* and *Hasan*
- Missing Narrators Level = "1", ">= 1" and ">= 2"
- Missing Narrators Position = Hadith Thabaqah, which are 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10

To conduct this, data of Hadith Narrators chaining was collected. The data was then analyzed to determine the fuzzy membership function as shown in Figure 6.

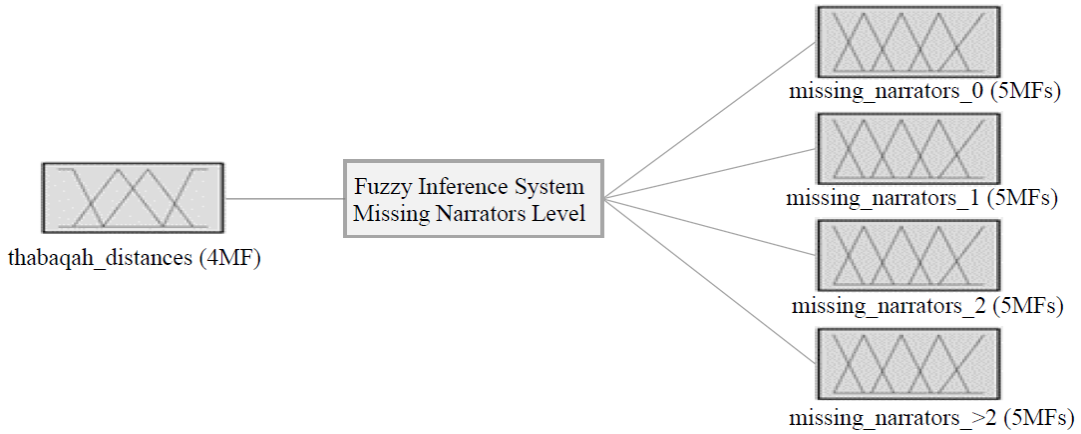

FIGURE 6. Fuzzy Inference System for the Missing Narrators Level

3.3.3. *Hadith Sanad Status Level.* The Hadith *Sanad* Status Level is defined for eight stages of *Sanad* Status: 1) *Sahih*; 2) *Hasan*; 3) *Mu'allaq*; 4) *Mursal*; 5) *Mu'dhal*; 6) *Munqathi'*; 7) *Matruk/Munkar*; and 8) *Mudraj/Maqlub/Muharraf/Mudallas.* Figure 7 and Figure 8 on sequence show fuzzy inference system results for the Hadith *Sanad* Status and its Membership Function.

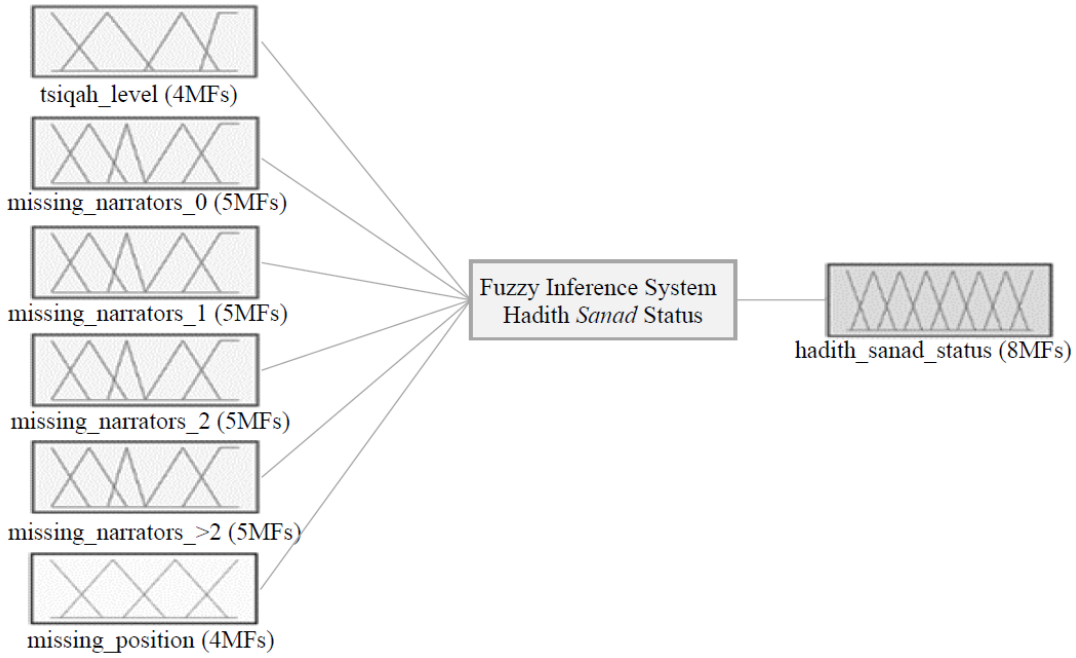

FIGURE 7. Fuzzy Inference System for the Hadith *Sanad* Status Level

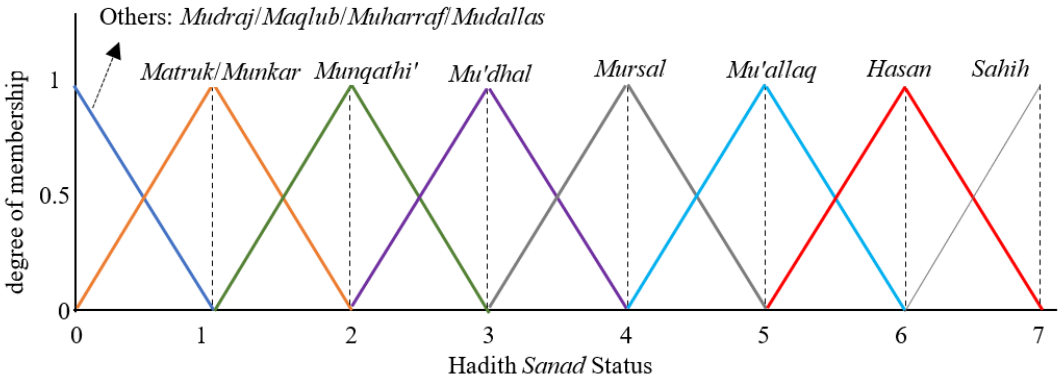

FIGURE 8. The Hadith *Sanad* Status membership function plot

The expression of the Hadith *Sanad* Status membership function is defined in the equation below.

$$\mu Others(X) = \begin{cases} (1-X) & 0 \le X \le 1 \\ 0 & X \ge 1 \end{cases} \tag{9}$$

$$\mu Matruk/Munkar(X) = \begin{cases} 0 & X \ge 1 \\ (X-0) & 0 \le X \le 1 \\ (2-X) & 1 \le X \le 2 \end{cases} \tag{10}$$

$$\mu Munqathi'(X) = \begin{cases} 0 & X \le 1 \text{ or } X \ge 3 \\ (X-1) & 1 \le X \le 2 \\ (3-X) & 2 \le X \le 3 \end{cases} \tag{11}$$

$$\mu Mu'dhal(X) = \begin{cases} 0 & X \le 2 \text{ or } X \ge 4 \\ (X-2) & 2 \le X \le 3 \\ (4-X) & 3 \le X \le 4 \end{cases} \tag{12}$$

$$\mu Mursal(X) = \begin{cases} 0 & X \le 3 \text{ or } X \ge 5 \\ (X-3) & 3 \le X \le 4 \\ (5-X) & 4 \le X \le 5 \end{cases} \tag{13}$$

$$\mu Mu'allaq(X) = \begin{cases} 0 & X \le 4 \text{ or } X \ge 6 \\ (X-4) & 4 \le X \le 5 \\ (6-X) & 5 \le X \le 6 \end{cases} \tag{14}$$

$$\mu Hasan(X) = \begin{cases} 0 & X \le 5 \text{ or } X \ge 7 \\ (X-5) & 5 \le X \le 6 \\ (7-X) & 6 \le X \le 7 \end{cases} \tag{15}$$

$$\mu Sahih(X) = \begin{cases} 0 & X \le 6 \\ (X-6) & 6 \le X \le 7 \end{cases} \tag{16}$$

3.4. **Create decision tables.** The next stage after creating a Mockler Chart is to create the HAFES decision table. It is essential to have a separate decision table for each triangle variable included in the Mockler Graphic. The process begins with the most important choice, then going backward from there. Each decision table will produce a rule set, and the Mockler Chart must be updated to include each rule set and its corresponding number label (triangle variable). The sum of the potential values that may be assigned to each condition determines the number of rows in each decision table. Table 5 and Table 6

TABLE 5. The *Tsiqah* Level Decision Table

Rule	Input				Output
	TS Level	TH Level	TMM Level	TO Level	*Tsiqah* Level
R1	very high	very low	very low	very low	very high
R2	very high	low	very low	low	very high
...	...	...	...	...	...
R50	very high	low	low	low	medium

TABLE 6. The *Tsiqah* Level rules

No	Rules	Weight
R1	IF [ts_level] IS very high AND [th_level] IS very low AND [to_level] IS very low AND [tmm_level] IS very low THEN [tsiqah_level] IS very high	1
R2	IF [ts_level] IS very high AND [th_level] IS low AND [to_level] IS very low AND [tm_level] IS low THEN [tsiqah_level] IS very high	0.9
...	...	...
R50	IF [ts_level] IS very high AND [th_level] IS low AND [to_level] IS low AND [tmm_level] IS low THEN [tsiqah_level] IS medium	0.05

define the *Tsiqah* Level Decision Table and its rules. The same concept is applied for the Missing Narrators Level and Hadith *Sanad* Status Level.

4. **Results and Evaluation.** The final part of the HAFES is the Fuzzy Inference System that is established in MATLAB software package for *Tsiqah* Level, Missing Narrators Level and Hadith *Sanad* Status as the output. The fuzzy inference system is taking min for the AND method and implication method, max for OR method, and aggregation method, and centroid for defuzzification method. The graphical indication of fuzzy inference system for Hadith *Sanad* Status is depicted in Figure 9.

The specific data used for the evaluation process is the output of each fuzzy inference model (*Tsiqah* Level, Missing Narrators Level, Hadith *Sanad* Level) compared with expected values from the references and human domain expert. In order to evaluate each fuzzy inference system, the accuracy, precision, and recall were calculated.

The *Tsiqah* Level was evaluated using 1,118 Hadith, the evaluation of Missing Narrators Level and Hadith *Sanad* Status Level was performed utilizing 5,910 data chain of narrators. The result for the output of the HAFES, that is the *Sanad* Status Level is shown in Table 7. Based on the accuracy value of 72.2%, the precision of 66.2%, and recall of 76.9%, it can be concluded that the fuzzy inference model for Hadith *Sanad* Level performs well. The expected output is obtained from established references as well as from the human domain expert. The Hadith Experts perform manual validation by comparing the expected output with the *Sanad* Status Output generated by the Hadith *Sanad* Status Fuzzy Inference System.

5. **Conclusions.** The Hadith Authentication Fuzzy Expert System (HAFES) is suggested in this study to assess the degree of Hadith *Sanad* Authenticity. The HAFES uses three elements to determine the Hadith *Sanad* Authentication Level: the *Tsiqah* Level, the Missing Narrators Level, and the Missing Narrators Position. All three parameters are defined as Membership Functions to conduct the fuzzification and transform a crips value into a fuzzy value. The result indicated that the HAFES performs well. The fuzzy inference model for the *Tsiqah* Level got an accuracy value of 92.72%, a precision of

FIGURE 9. The Hadith *Sanad* Status Fuzzy Inference System

TABLE 7. The Hadith *Sanad* Status evaluation

Fuzzy inference system output	Accuracy	Precision	Recall
Sahih	79.6%	73.1%	82.3%
Hasan	75.8%	69.6%	82.3%
Matruk/Munkar	69.0%	63.3%	68.4%
Others	51.0%	46.8%	74.7%
Overall	72.2%	66.2%	76.9%

98.12%, and a recall of 98.12%. The fuzzy inference model for Missing Narrators Level got an accuracy value of 98.16%, a precision of 97.16%, and a recall of 97.10%. And the final fuzzy inference model for Hadith *Sanad* Status Level got an accuracy value of 72.2%, a precision of 66.2%, and a recall of 76.9%.

Acknowledgment. We acknowledge financial assistance and support from Universiti Teknikal Malaysia Melaka and Universitas Amikom Yogyakarta. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

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