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A FUZZY SYSTEM FOR EVALUATING TRUSTWORTHINESS OF USERS IN A SOCIAL NETWORK

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ABSTRACT: In recent years, the emergence of various web-based social networks has led to the growth of social network users. These networks have become popular as a medium for disseminating information and communication. Governments and organizations also use social networks as a platform for better services. However, acting in such networks depends on the level of trust that members have with each other. The combination of personality attributes of a person can create a mental impression of the amount of trust that a person has. This amount of trust can affect the person's future interactions. Therefore, trust is an essential and important matter in these networks, especially when someone interacts with someone else on a web-based social network. We discuss this issue in this paper and provide a method for evaluating it. Measuring the accuracy is not easy for the users who are interacting with the social network. Here, the interactions are virtual. In this paper, we have used fuzzy logic to apply ambiguous data and to evaluate trustworthiness by taking into account the various personality attributes of users such as reliability, availability, interest, patience, and adaptability. As we used these attributes as input to the fuzzy system and based on the relevant fuzzy rules, we evaluated the trustworthiness of users in social networks. The proposed fuzzy system is extendable, because in this system, trust can be defined as a set of one or more personality attributes. Epinions social network dataset is also used to simulate and validate the proposed approach. In the proposed method, the MAE value is less than 0.015 and F-Score value more than 0.86. Based on the results, the presented fuzzy system shows an acceptable accuracy for evaluating the trustworthiness of users.

ABSTRAK: Sejak beberapa tahun kebelakangan ini, kemunculan pelbagai rangkaian web sosial telah menyebabkan pertumbuhan pengguna rangkaian sosial. Rangkaian ini telah menjadi popular sebagai medium penularan informasi dan komunikasi. Kerajaan dan organisasi juga menggunakan rangkaian sosial sebagai platfom bagi menyediakan servis perkhidmatan terbaik. Namun, pemakaian rangkaian ini bergantung kepada kepercayaan pengguna antara sesama pengguna. Gabungan ciri-ciri personaliti terhadap seseorang menyebabkan terciptanya persepsi secara mental pada kepercayaan ke atas seseorang. Jumlah kepercayaan ini akan memberi kesan terhadap interaksi yang akan berlaku pada masa depan ke atas individu tersebut. Oleh itu, kepercayaan sangat penting dalam rangkaian ini, terutama apabila seseorang berinteraksi dengan mereka di jaringan sosial web. Isu ini dibincangkan dalam kajian ini dan kaedah evaluasi turut dihuraikan. Mengukur ketepatan pengguna dalam jaringan sosial tidak mudah. Di sini, interaksi berlaku secara maya. Kajian ini menggunakan logik kabur pada data tidak jelas dan bagi mengukur tahap kepercayaan, pelbagai ciri personaliti individu diukur, seperti kebolehpercayaan, kebolehdapatan, minat, kesabaran dan kebolehsesuian. Ciri-ciri tersebut digunakan sebagai input kepada sistem rawak dan berdasarkan peraturan rawak, tahap kebolehpercayaan pengguna diukur dalam rangkaian sosial. Sistem rawak yang dicadangkan ini boleh dilanjutkan, kerana dalam sistem ini kepercayaan boleh dimaksudkan sebagai satu set atau lebih ciri-ciri personaliti. Anggapan pada set data rangkaian sosial turut digunakan bagi simulasi dan pengesahan kaedah yang dicadangkan. Bagi kaedah yang dicadangkan ini, nilai MAE adalah kurang daripada 0.015 dan nilai skor-F lebih daripada 0.86. Berdasarkan dapatan kajian ini, sistem rawak yang dikaji ini menunjukkan ketepatan yang boleh diterima bagi mengukur tahap kebolehpercayaan pengguna.

KEYWORDS: *social network; web-based social network; fuzzy logic; trust*

1. INTRODUCTION

Trust is a multifaceted concept that can be defined differently according to its application, so it is difficult to determine trust and it is possible to make a mistake. Different domains have brought about different definitions concerning the concept of trust some of which are referred to below. In [1] and [2] psychologists, in their studies, concluded that trust focuses on the mind-set of an individual when he trusts or distrust someone. In [3], trust in computer science generally divides into two parts: 1- User, 2- System. In [4], with respect to a transaction, trust was considered as a relationship between trustor (someone who trusts) and trustee (one who has been trusted). An analysis of [5] for trust in web-based social networks can be found on the basis of the belief that a person has some actions that will bring good results in the future. Based on the definitions given above, this inference stems from different interpretations that may take place with respect to the place and application of the trust. In social networks, one of the topics where trust plays a vital role is the creation and maintenance of relationships, so that one can say that the basis of any relationship is trust.

In web-based social networks, the amount of individual's trust comes from his virtual personality due to his interactions on the web and it can’t be compared with daily life as that is face to face. The virtual personality of a person depends on personality attributes that they have viewed virtually. Some of the personality attributes that lead to the trustworthiness of users can be reliability, availability, interest, patience, and adaptability. The point that matters is that these attributes are internal and can be interpreted in a variety of ways, based on a definition that we provide about trust. In this research, we have proposed a method in which the trustworthiness of users can be evaluated depending on one or more personality characteristics. The rest of the paper is organized as follows. In section 2, social networks and related properties are expressed. Section 3 discusses related works about trust in social networks. Section 4 explains the fuzzy system proposed for evaluating trustworthiness. Section 5 describes the evaluation of the proposed the fuzzy system and section 6 discusses the conclusion and future works.

2. SOCIAL NETWORKS AND TRUST MANAGEMENT

Social networks can be specified as a set of nodes and edges that are systematic, so that the nodes describe users, groups, and communities and the edges describe communications. Web-based social networks provide another way to communicate with others, affecting social relationships in the real world. It can be said that many of the relationships created in these networks, despite being virtual, are stronger than real-world relationships [6]. Several definitions of a social network have been proposed in various domains. For example, [7] proposed a graph-based framework with the structure of a decentralized system.

2.1 Social Network Properties

In [8], properties of social networks have been discussed, including the phenomenon of homophily and the small world. Homophily means the readiness of users to cooperate, to establish relationships and to make pledges with others. In [9], homophily is discussed in two types. The first type is status homophily, where users tend to associate with those who have similar social attributes with them, such as race, age, occupation, etc. The second type is value homophily, which is based on values, attitudes, and beliefs. This means that users tend to associate with the users who have similar thinking without considering their situation. The phenomenon of the small world visualizes the world as a “small world”, where all users are linked by a small chain. For example, users with similar interests are associated together with web-based social networks.

2.2 The Importance of Trust in Social Networks

The growth of web-based social networks in online communities has become a major source of communication and can be seen from the popularity of social network sites such as Facebook, YouTube, Instagram, and so on [6]. This popularity has been the impetus for the production and growth of many web-based social networks in specific communities. Lots of social networks currently is use are designed to connect and interact with different users in different places [8].

In social networks, the concept of FOAF (Friend of a Friend) has many uses. This concept suggests that someone can interact with a friend of friends and engage in friendship. Given the fact that the trust is the basis of each friendship, trustworthiness may not be true for a friend of friends. For this reason, one of the risks is the security of private data on social networks, according to the concept of FOAF. Such risks have been experienced on social networking sites and are reported in [8, 20].

2.3 Trust Management in Social Network

In [11], trust management systems are classified into three categories: 1) credential and policy-based, 2) reputation based, and 3) social networks based. The main purpose of the first category, which is credential and policy-based, is validating the entity to enable access control. The second category, which is reputation based, builds trustworthy and secure communications by evaluating the reputation and popularity of the entity in the environment. The third category in trust management systems, which is based-on social networks in addition to considering the reputation, use social relationships among peers to establish the trusted relationships.

3. RELATED WORKS

In [1], trust in social networks has been investigated. In [4], an approach was proposed to determine the quantitative content of the shared contents in terms of its trustworthiness. Authors focused on determining trustworthiness of shared content in the health domain as the negative impact of acting on untrustworthy information is high in this domain. In [12], authors provided algorithms for inferring trust among individuals who are not familiar with or interact with each other. Also, a way to extract information and integrate it into applications was investigated. The algorithms proposed for inferring trust depend on the reputation information.

In [13], an algorithm called TidalTrust was proposed to infer trust. The algorithm described in [13] cannot be properly executed to determine the trustworthiness of the Users based on the attributes provided. In [14], a system called PowerTrust was used to calculate peer-to-peer trust. The scalable system had a useful performance but could not be used to build trust in a social network.

In [15], a model for trust evaluation based on gravity was discussed. The proposed method was a two-step process. In the first stage, friendships and strengths were calculated, and in the second stage, the social neighbour was applied to calculate the trust. This model could not evaluate the trustworthiness of the users depending on their personality attributes. Algorithms for calculating behavioural trust were proposed in [16]. The purpose of this paper was to quantify dual trust based on the observed communication pattern. These actions are statistically defined and do not use any semantic information contained in the messages. In [17], social trust was discussed. Two algorithms were presented that access to implicit and explicit social trust. The proposed approach was more robust against manipulation attacks and had its applicability in fields like secure DTN routing. The approach was not directly applicable for evaluating trustworthiness of users in a social network. In [18], a model called STrust was designed to create trusted societies in which members could share their information without worry. The model relied on social capital to derive trust value.

In [19], trust management was discussed as it relates to Internet applications. A notation for specifying trust and recommendation concepts was presented along with a set of tools for specifying, analyzing and monitoring trust relations. In [20], Shirgahi et al. used parameters of social network authority, the value of pages' links authority and semantic authority to assess the trust. In [21], the importance of the trust model was discussed based on user beliefs and credibility. The model is not applicable in the present form to evaluate trustworthiness of users in a Web-based social network. The purpose pursued in [22] was the design of a fuzzy system. This trust model was used in distributed systems, but it could not predict the trust of users in social network. In [23], a genetic algorithm-based approach to inferring trust was introduced. The approach used heterogeneous relations for inferring trust. The algorithm achieved higher accuracy for trust values and was scalable and extensible, but it did not evaluate trustworthiness of users in a social network. The focus of [24] was on graphical representation for modelling trust relationships in multiagent e-commerce environments. The work was not applicable for evaluating trustworthiness of users in a Web-based social network. In [25], a subjective logic to express distrust and to evaluate the trust probability distribution was suggested, but this method could only be used for the binary trust model. In [26], Danesh and Shirgahi provided a way to predict trust in a social network with structural similarities through the neural network. In this method, the web of trust data set was first converted to a structural similarity data set based on the similarity of the trustors and trustees. Then, on the created data set, 70% of the data set was considered as the training data and it was trained based on the multilayer perceptron neural network. Finally, the trained neural network was tested based on the test data.

None of the above-mentioned models could evaluate users' trustworthiness based-on a set of personality attributes. In this research, an approach is adopted in which trustworthiness of users can be evaluated based-on a set of personality attributes. This approach supports an unlimited number of personality attributes that can be defined. In the next section, we will explain the proposed approach.

4. THE PROPOSED APPROACH FOR EVALUATING TRUSTWORTHINESS

A web-based social network can be implemented as a directed graph G (V, E) so that V is a set of nodes that denotes users and E is the set of edges that describe the interactions between these users. The number assigned to each edge from vi to vj (user i to user j), indicates the number of times the user i interacts with the user j. As an example, Fig. 1 illustrates a simple example of this network. This figure consists of a directed graph and the nodes' interactions with each other. The values on each edge represent the total number of interactions performed by the user with the other users. It should be noted that in this figure, for example I1 is the same as Individual1.

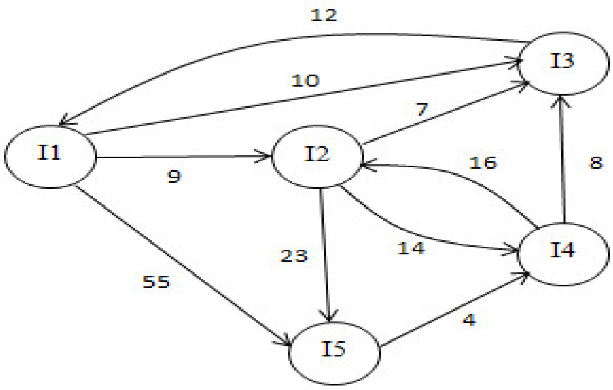

Fig. 1: Web-based social network.

Interactions are different in nature and are based on the rate. The rate of the users interacting corresponds to various attributes. The rating depends on the experience and the feelings received by the users. Rating values are processed using fuzzy logic to evaluate trustworthiness. The two most important criteria of graph that are used to evaluate trustworthiness of users are called In-degree and Out-degree. The In-degree of a node points to the number of the other users interacting with the selected user, and Out-degree of a node points to the number of the users that the selected user interacts with [6]. In other words, it can be said that In-degree node states that the selected user receives information about the other users, and Out-degree node points to the fact that the selected user disseminates information on his personality attributes on the social network to the other users.

Low In-degree and Out-degree nodes denote less interactivity, in other words receiving or disseminating less information; and High In-degree and Out-degree nodes denote more interaction, that is receiving or disseminating more information.

Clearly, it is difficult for a user at Low In-degree to directly determine the trustworthiness of others. The proposed approach requires that each participant (for example, a user) receives ratings of each entity's different attributes with which he is interacting. A rating reflects experiences perceived by each entity about another one based on the attribute selected. Each scale can be used to rate the attributes from -S to +S.

That means, if S=2, then the scale is from -2 to +2. Table 1 shows the rating scale for five personality attributes and their meanings.

In this paper, we chose these five personality attributes based on our own mental perceptions and our studies.

Reliability expresses user ability to do something without failure. Availability indicates that users are always available to interact with and support each other. Interests include factors that make a user attractive. In fact, the more users' interests are similar, the more they can trust each other.

Patience means that a patient user is able to tolerate setbacks, delays, or unexpected challenges without becoming anxious or angry. A patient user has a better mental health. Adaptability is the emotional and current stability of social relationships. An adaptable user can quickly adapt to changes in plans. A user that is adaptable is associated with his various traits and characteristics.

Table 1: Five characteristics and their concepts

Rate	Reliability	Availability	Interest	Patience	Adaptability
-2	Ever unreliable	Ever unavailable	Ever dissimilar interests	Ever impatience	Ever unadaptable
-1	Often unreliable	Often unavailable	Often dissimilar interests	Often impatience	Often unadaptable
0	No comment	No comment	No comment	No comment	No comment
1	Often reliable	Often available	Often similar interests	Often patience	Often adaptable
2	Ever reliable	Ever available	Ever similar interests	Ever patience	Ever adaptable

It is important to note that the proposed method is general and does not depend on the number of attributes. That is, trustworthiness can be considered as a function of characteristics and this is because trust is a mental concept, and it takes different interpretations depending on the conditions and applications. However, to show the usability of the fuzzy system proposed through simulation, 5 attributes have been selected. Trustworthiness is considered as a function of these 5 attributes. Also, the proposed approach has no limitations on the scales used to rate the experiences for simulation.

In general, each rating scale from -S to + S, where S> 0, can be used. An experiences record, in the form of rating various characteristics during different interactions, is maintained by the user about the other user he interacts with. With these experiences, the experience matrix can be formed. Experiences with different parameters in various interactions are stored in the experience matrix.

The experience matrix is used as an input to a fuzzy system to analyse the others' trust. In evaluating the attributes of experience, consider that the user U1 interacts with the user U2 with n interaction. EC_{att} (U1, U2) as a set of experience consisting of n values that represent the feeling experience of the user u1 about the user u2 in n interactions according to attribute defined as follows.

$$EC_{att}(u1, u2) = \{exp_{att},1, exp_{att},2, \ldots, exp_{att}, n\}$$

As exp_{att}, n is an experience feeling by the user U1 about the user U2 with respect to the $_{att}$ attribute in the nth interaction. EC_{att} values are recorded by each user for all the users they interact with. That way we can define whole expertise perceived through by user U1 for user U2 with respect to the $_{att}$ attribute, as

$$EC_{att}(u1, u2) = \text{mode}\,(EC_{att}(u1, u2))$$

In it, EC_{att} (u1, u2) is the whole experience felt by the user U1 for the user U2 according to the $_{att}$ attribute and the mode (EC_{att} (u1, u2)) is the mode value of the EC_{att} (u1, u2) set.

This Process can be generalized to gain experience of the users about others due to various attributes. Figure 2 is pseudo code that represents a procedure for calculating the experience of the users from the other users. Low values In and Out-degree between U1 and U2 provide less accuracy EC_{att} (U1, U2), while High values provide greater accuracy EC_{att}(U1,U2) Results, while High values provide greater accuracy EC_{att} (U1, U2) Results.

4.1 Generating of Matrix of Experience(EM)

Figure 2 shows the pseudo-code for calculating the experience matrix. For example, Table 2 shows ratings for first user interaction with another user on the five characteristics. By the pseudo-code written in Fig. 2, Table 3 is obtained from Table 2. From Table 3, the matrix of experience is achieved that is shown in Fig. 3. After the matrix of experience is obtained, depending on one or more characteristics, trust can be calculated.

The user can pick the attributes. In fact, the user chooses the specific attributes according to his needs and understanding of trust. The fuzzy system we provided can be used to evaluate trust depending on one or more characteristics. Here, it's important to note that choosing the attributes of trust may vary for each user. This standard of system enables a user to model trust based on his own understanding of what happens in the real world.

```
U1: first user
Un: nth user
X,Y: Temp user variables
k = the number of attributes
X=U1;
While (X<=Un)
{
        While (Y<=Un)
        {
            If (X!=Y)
            {
             For (att=att1; att<=attk; att++)
                {
                 Eatt(X, Y) = mode (ECatt)
                 }
              }
           J++;
            }
    I++;
     }
```

Fig. 2: Pseudo-code for calculate expertise of the users.

Table 2: Ranking for first user interaction with another user on the five characteristics

Users	Count of interaction	Attributes				
		Reliability	Availability	Interest	Patience	Adaptability
U_2	8	-1,-1,0,1,2,-1,0,1	-2,-2,0,-1,-2,1,0,2	-1,1,0,-1,2,0,1,-1	-1,-2,-1,-2,1,2,-1,0	-2,-1,-1,0,1,-2,-2,-1
U_3	6	2,1,1,2,1,2	1,2,2,1,1,1	1,1,0,2,1,0	-2,-2,1,1,0,-2	2,1,1,0,2,2
U_4	5	1,2,0,2,1	0,1,2,2,2	-2,2,-2,1,0	-1,2,-1,0,1	1,1,1,2,1
U_5	4	-1,-2,-1,-1	-2,-2,-2,-1	-2,-1,-1,-1	-1,-2,-2,-2	-1,-1,-2,-1
U_6	9	1,0,0,1,1,0,1,0,0	0,1,1,1,0,1,0,1,1	1,0,0,1,0,0,1,1,0	1,0,0,-1,-1,0,-1,-1,1	1,1,1,1,0,0,1,0,0

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Table 3: User 1's ranking of five characteristics of the other users

Users	Attributes				
	Reliability	Availability	Interest	Patience	Adaptability
U_2	-1	-2	-1	-1	-2
U_3	2	1	1	-2	2
U_4	1	2	-2	-1	1
U_5	-1	-2	-1	-2	-1
U_6	0	1	0	-1	1

$$EM = \begin{bmatrix} -1 & -2 & -1 & -1 & -2 \\ 2 & 1 & 1 & -2 & 2 \\ 1 & 2 & -2 & -1 & 1 \\ -1 & -2 & -1 & -2 & -1 \\ 0 & 1 & 0 & -1 & 1 \end{bmatrix}$$

Fig. 3: Matrix of experience of user U1.

4.2 Fuzzy System for Trust Evaluation of Users

Fuzzy logic has been used to evaluate the trustworthiness based on a rating of 5 personality attributes that have been considered. We use fuzzy logic because there aren't any exact boundaries for separating these interdependent attributes. According to the initial definition, a fuzzy system has three parameters which include inputs, fuzzy inference system and output.

Inputs and outputs are the same as the input and output data we want. The fuzzy inference system uses fuzzy rules to obtain the output. Figure 4 illustrates our fuzzy system. Fuzzy system inputs have five attributes: reliability, availability, interest, patience, and adaptability and the fuzzy system output is trustworthiness. The final values of the ranking of these attributes are obtained by the fuzzy rules that are defined.

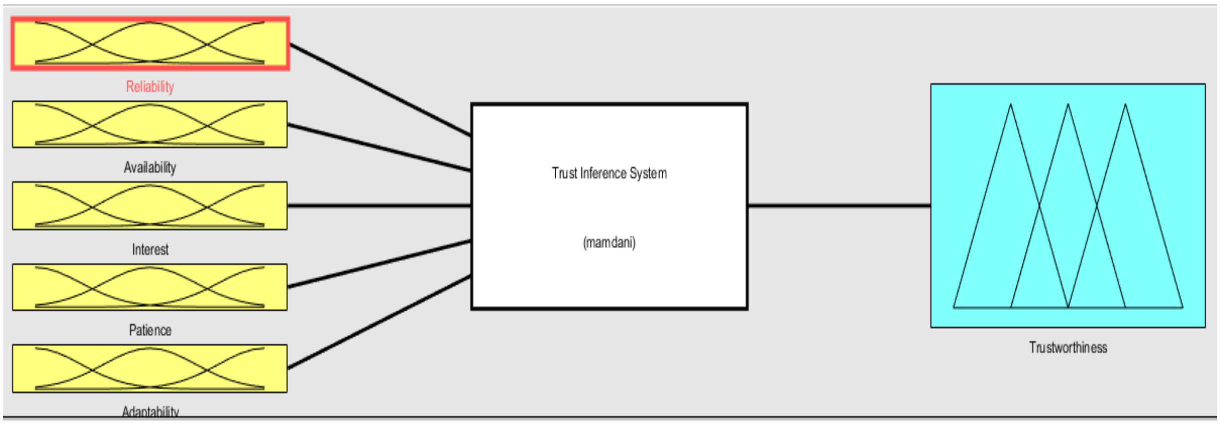

Fig. 4: Overview of fuzzy logic-based trust inference system.

All five attributes that are our fuzzy system inputs have been rated in Table 1. The histogram of the inputs and output variables is shown in Fig. 5. Also, in Fig. 6, the fuzzy sets related to our input and output variables are also shown.

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The most important part in fuzzy systems is their rules, they connect the conceptual relation of the input parameters to the output parameters. In this paper these rules are written according to the train datasets. Figure 7 shows an illustration of the rules defined. In general, the 252 fuzzy rules that were used to simulate 5 attributes to gain trustworthiness are included. It is worth noting that any number of attributes can be considered, but as the number of attributes increases, the number of rules can increase exponentially, and as a result, the inference process of the fuzzy system becomes more complicated and the runtime is increased.

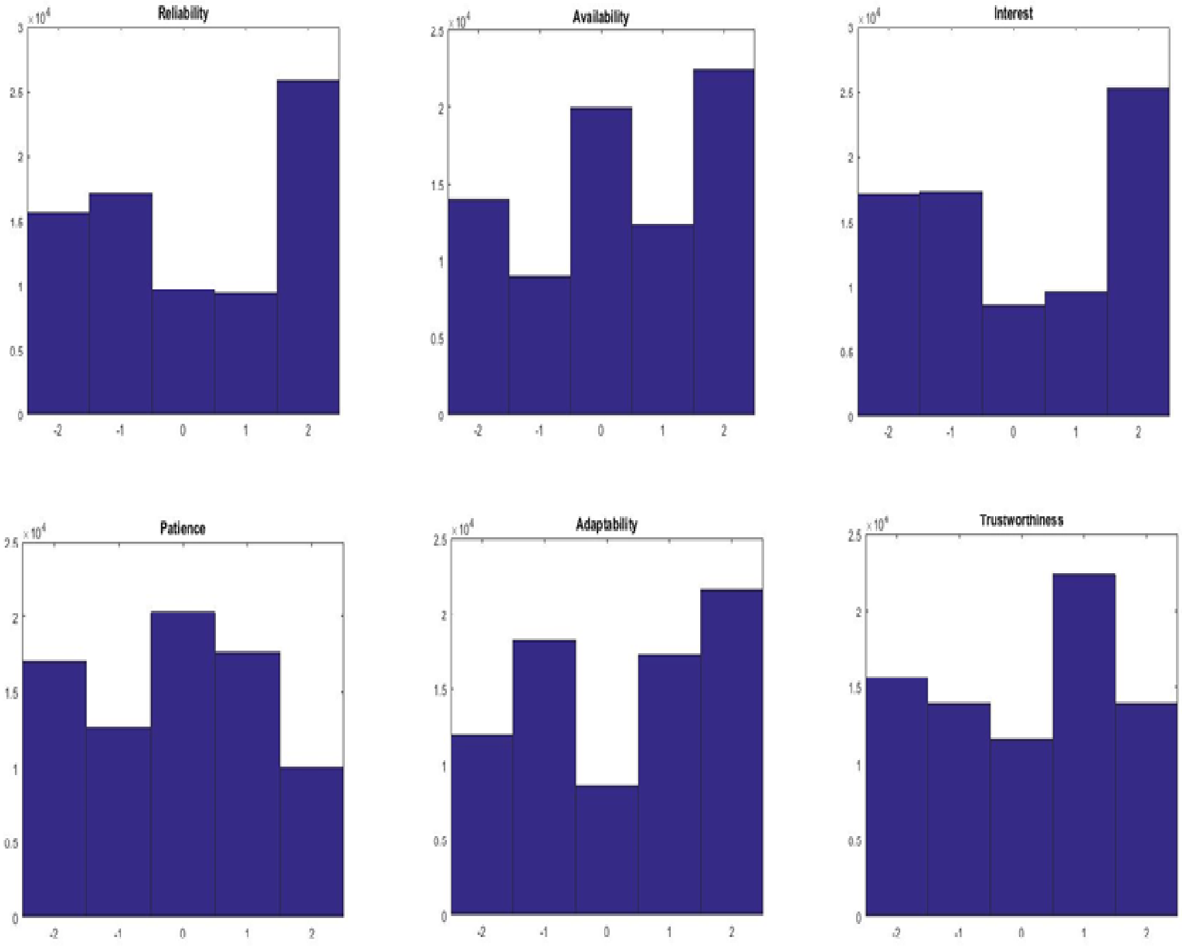

Fig. 5: Histogram diagram of the input and output variables.

Figure 8 contains the Rule Viewer of a fuzzy system that executes related rules for specific entries and displays the defuzzification final output value.

5. EVALUATING THE PROPOSED APPROACH

To evaluate the proposed approach, we have used the Epinions dataset, which is a social network dataset. In this way, we performed our own assessment on a part of the data set, including the first 2000 nodes and 77589 edges. One of the benefits of this dataset is that it is a real dataset and is widely used in research in the field of social networking. To simulate this approach, the MATLAB tool and Mamdani Fuzzy Inference System are used to assess the trustworthiness of the users.

During the simulation of the output of the fuzzy system, according to Table 4, the trustworthiness was classified into 5 categories.

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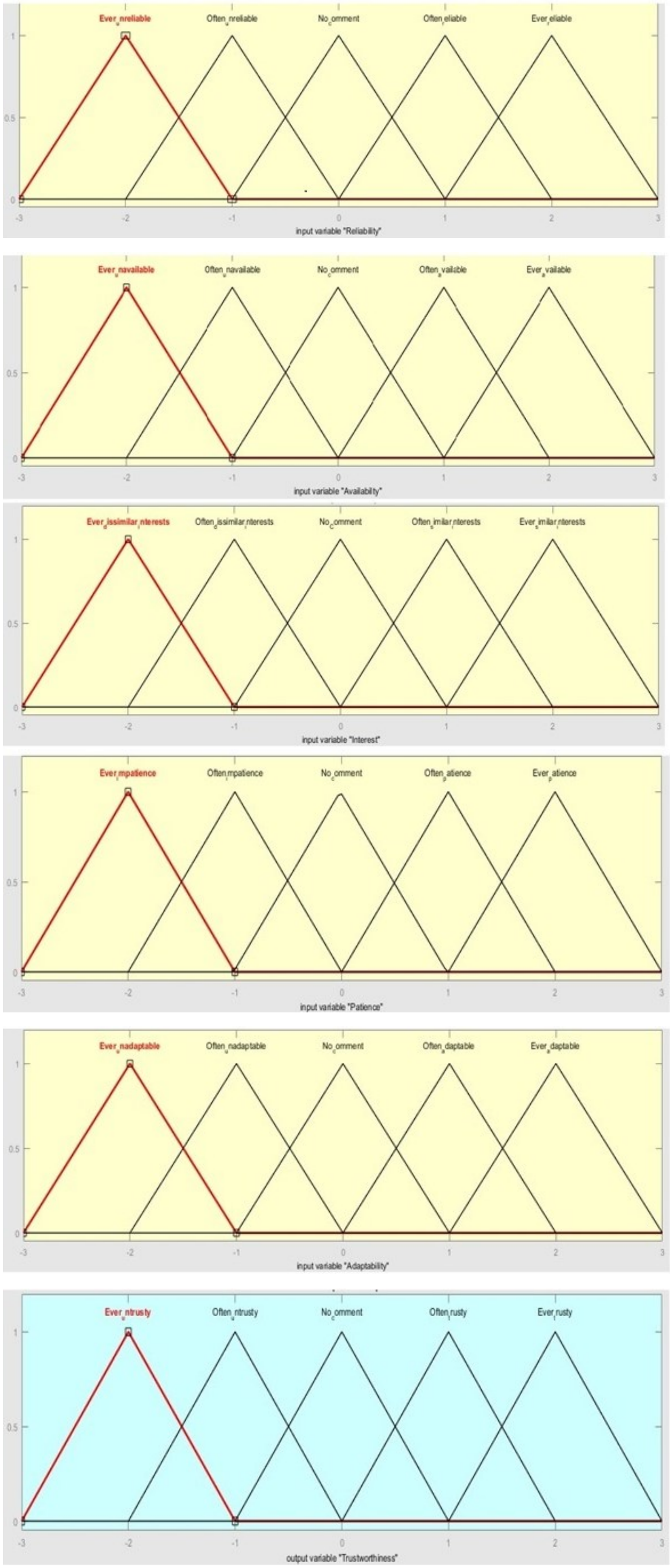

Fig. 6: Fuzzy sets related to our input and output variables.

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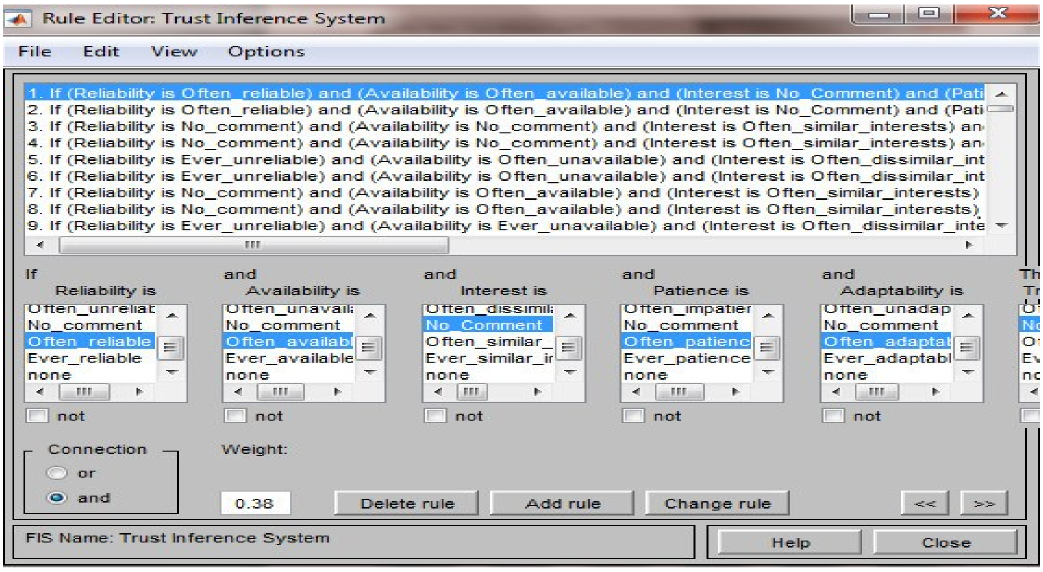

Fig. 7: Illustration of the defined rules.

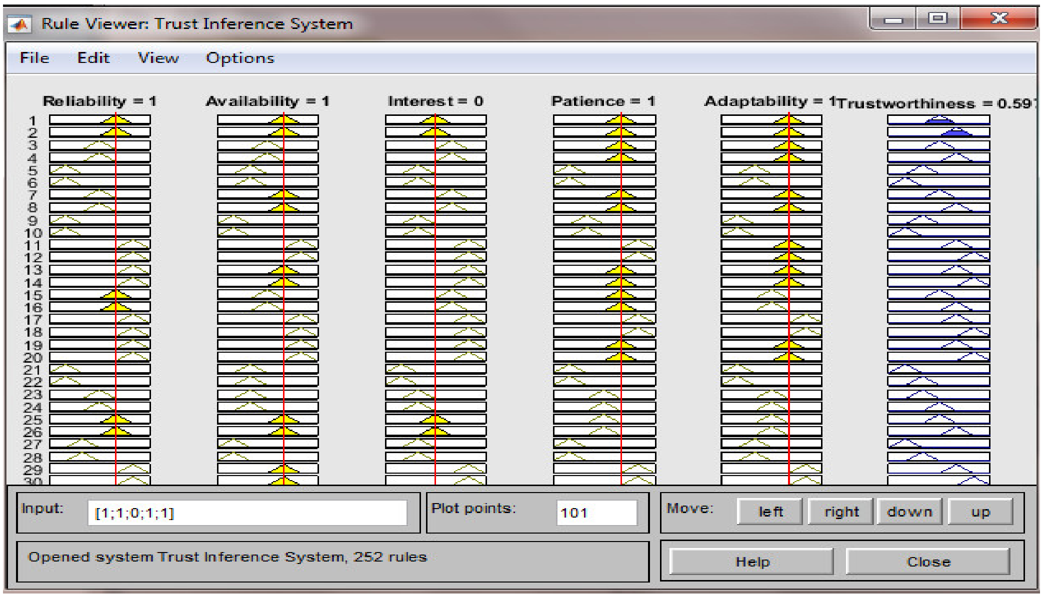

Fig. 8: Rule Viewer of fuzzy system.

Table 4: Trustworthiness categories of users

Rating Category	Trustworthiness
-2	Ever untrusty
-1	Often untrusty
0	No comment
1	Often trusty
2	Ever trusty

For a more accurate evaluation of the fuzzy system, we have examined various types of fuzzy systems, which are presented in Table 5. For the input and output variables, we used the Trimf membership function. The overall structure of this function is given in Eq. (1).

$$f(x;a,b,c)=\begin{Bmatrix} 0, x \le a \\ \frac{x-a}{b-a}, a \le x \le b \\ \frac{c-x}{c-b}, b \le x \le c \\ 0, c \le x \end{Bmatrix} \quad (1)$$

As shown in Table 5, the bases of fuzzy logic used min, prod methods in which the overall structure of the fuzzy reasoning methods are based on Eqs. (2) and (3).

$$min(a,b)=\begin{Bmatrix} a, a \le b \\ b, a \succ b \end{Bmatrix} \quad (2)$$

$$prod(a,b)=a*b \quad (3)$$

We used gravity centre (centroid), bisector, MOM (Mean of Maximum) and SOM (Smallest of Maximum) methods for defuzzification, which are given in Eqs. (4) to (6).

$$x_{centroid} = \frac{\int x \times \mu_i(x)\,dx}{\int \mu_i(x)\,dx} \quad (4)$$

$$\int_{\alpha}^{x_{bisector}} \mu_i(x)\,dx = \int_{x_{bisector}}^{\beta} \mu_i(x)\,dx \quad (5)$$

$$MOM\ (a,b) = (a+b)/2 \quad (6)$$

Table 5: Features of the different fuzzy system

FIS Name	FIS Type	MF Type	And Method	Or Method	Implication Method	Aggregation	Defuzzification Method
FIS 1	mamdani	trimf	min	max	min	max	centroid
FIS 2	mamdani	trimf	prod	max	prod	max	centroid
FIS 3	mamdani	trimf	min	probor	min	probor	centroid
FIS 4	mamdani	trimf	prod	probor	prod	probor	centroid
FIS 5	mamdani	trimf	min	max	min	max	bisector
FIS 6	mamdani	trimf	prod	max	prod	max	bisector
FIS 7	mamdani	trimf	min	probor	min	probor	bisector
FIS 8	mamdani	trimf	Prod	probor	prod	probor	bisector
FIS 9	mamdani	trimf	min	max	min	max	MOM
FIS 10	mamdani	trimf	prod	max	prod	max	MOM
FIS 11	mamdani	trimf	min	probor	min	probor	MOM
FIS 12	mamdani	trimf	prod	probor	prod	probor	MOM
FIS 13	mamdani	trimf	min	max	min	max	SOM
FIS 14	mamdani	trimf	prod	max	prod	max	SOM
FIS 15	mamdani	trimf	min	probor	min	probor	SOM
FIS 16	mamdani	trimf	prod	probor	prod	probor	SOM

5.1 Parameters of Fuzzy System Performance Evaluation

After simulating the fuzzy system described in evaluating the proposed approach, to evaluate the performance of the different fuzzy systems, we considered 10% of the dataset to use as test data and examined the performance of fuzzy systems. For evaluating the fuzzy system performance from various measures including precision, recall, and F-score, we compared them with each other. How to calculate the Precision, recall and F-score is noted in Eqs. (7), (8), and (9), respectively.

$$\text{precision} = \frac{\text{TruePositive}}{(\text{TruePositive})+(\text{FalsePositive})}\times 100 \tag{7}$$

$$\text{recall} = \frac{\text{TruePositive}}{(\text{TruePositive})+(\text{FalseNegative})}\times 100 \tag{8}$$

$$\text{F-score} = \frac{2\times\text{recall}\times\text{precission}}{\text{recall}+\text{precission}} \tag{9}$$

We also calculated the error obtained from the trustworthiness by different fuzzy systems in comparison with the trustworthiness in test data of the main dataset as MAE's (Mean Absolute Error), which is given in Eq. (10). According to Eq. (10), CTi refers to the calculated value of trust, and RTi is the real trust value, and N is the total number of test data.

$$\text{MAE}=\frac{\sum_{i=1}^{N}|C_{Ti}-R_{Ti}|}{N} \tag{10}$$

The numbers derived from the calculation of these measures and the error rate obtained on the test dataset in various fuzzy systems are given in Table 6.

Table 6: Calculation of these measures and the error rate in fuzzy systems

Fis name	Precision	Recall	F-score	error
FIS1	0.8222	0.9547	0.8835	0.0085
FIS2	0.8222	0.9547	0.8835	0.0071
FIS3	0.8222	0.9547	0.8835	0.0089
FIS4	0.8222	0.9547	0.8835	0.0076
FIS5	0.7991	0.9654	0.8744	0.0062
FIS6	0.7991	0.9654	0.8744	0.0048
FIS7	0.8222	0.9547	0.8835	0.0074
FIS8	0.8222	0.9547	0.8835	0.0060
FIS9	0.7991	0.9654	0.8744	0.0014
FIS10	0.7991	0.9654	0.8744	0.0016
FIS11	0.7991	0.9654	0.8744	0.0077
FIS12	0.7991	0.9654	0.8744	0.0016
FIS13	0.7991	0.9654	0.8744	0.0068
FIS14	0.7991	0.9654	0.8744	0.0016
FIS15	0.7991	0.9654	0.8744	0.0077
FIS16	0.7991	0.9654	0.8744	0.0016

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Also, the comparison of precision measures for various fuzzy systems is in Fig. 9. According to Fig. 9 the best result belongs to FIS1-4 and FIS7-8 with 0.822. The comparison of the recall measures for various fuzzy systems is shown in Fig. 10. The results of Fig. 10 show that FIS5-6 and FIS9-16 have achieved the highest recall with 0.9655. The comparison of the F-score measure for various fuzzy systems is presented in Fig. 11. According to Fig. 11, FIS1-4 and FIS7-8 have achieved the highest F-score with 0.8835 and the comparison of the obtained error rate for various fuzzy systems is shown in Fig. 12 which shows the results in Fig. 9 have the lowest error mid with 0.0014.

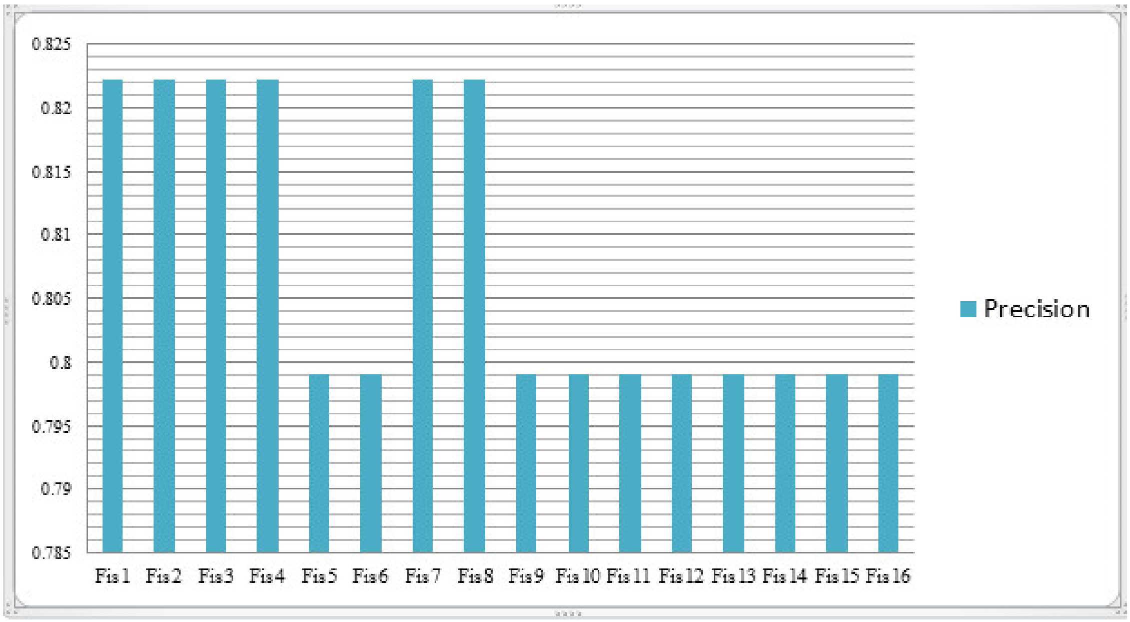

Fig. 9: Comparison of the precision measure for various fuzzy systems.

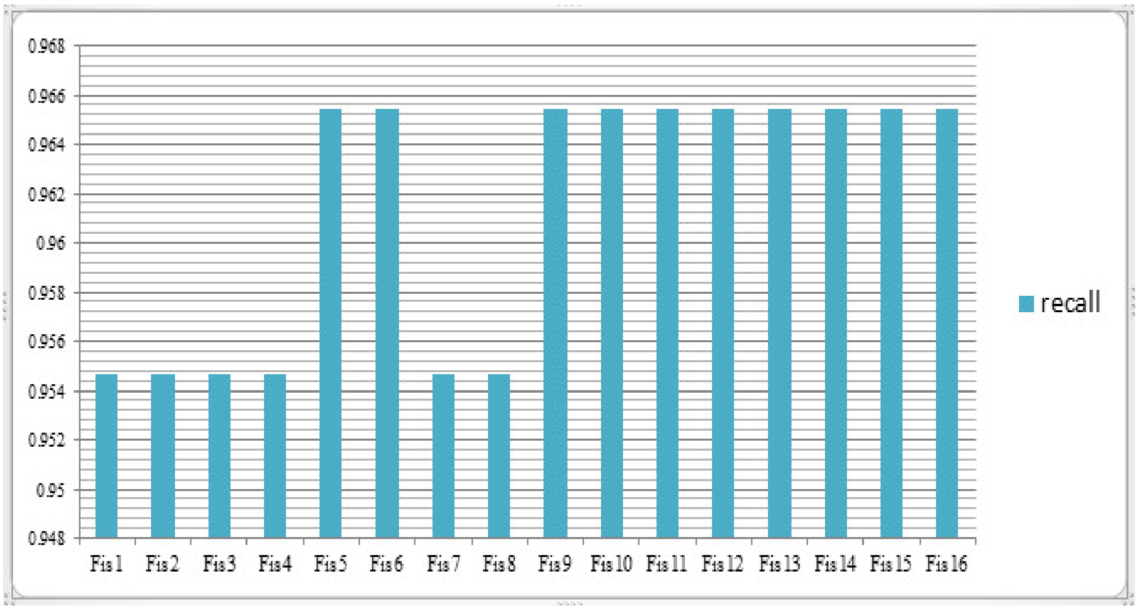

Fig. 10: Comparison of the recall measure for various fuzzy systems.

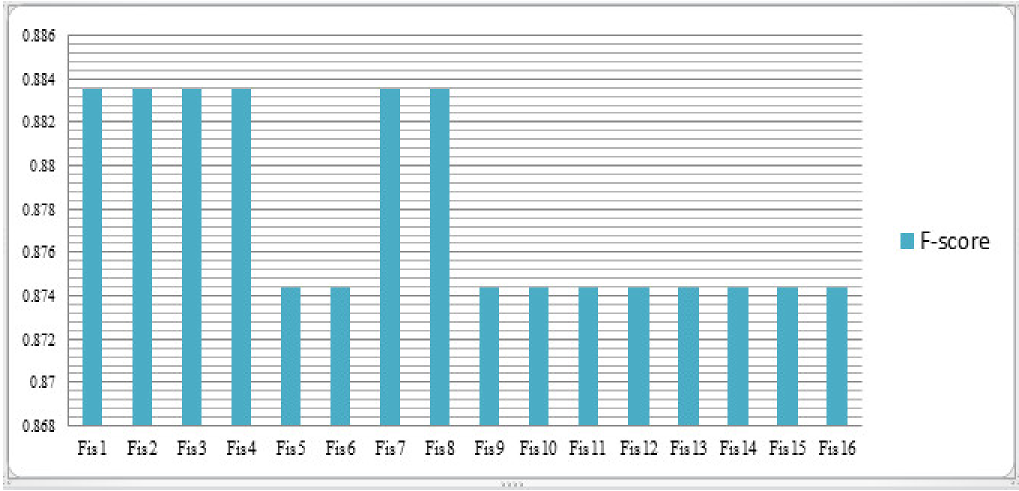

Fig. 11: Comparison of the F-score measure for various fuzzy systems.

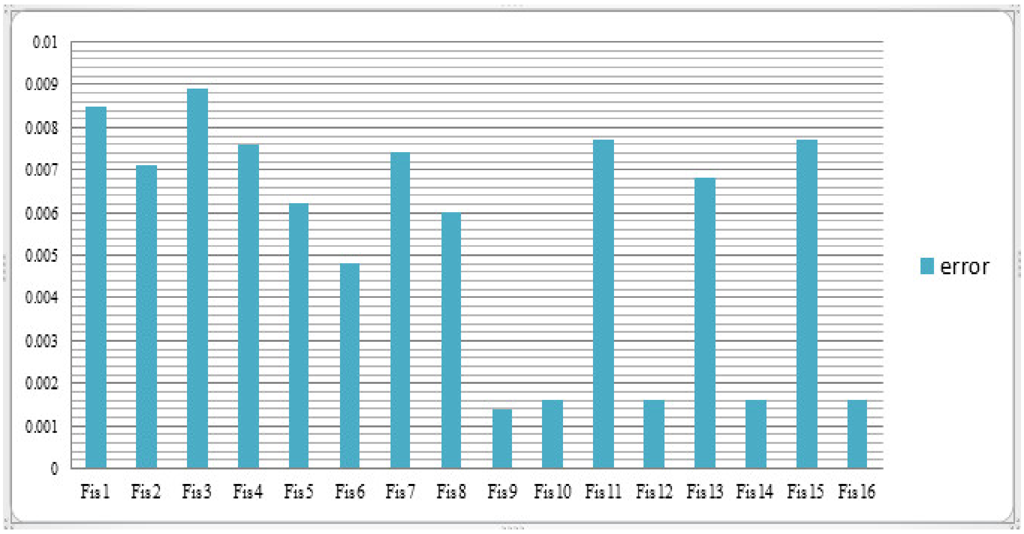

Fig. 12: Comparison of the obtained error rate for various fuzzy systems.

6. CONCLUSION

In this paper, we proposed and discussed a fuzzy system for evaluating trustworthiness of the users based on personality attributes in a social network. In the proposed system, our method includes a ranking of 5 personality characteristics such as reliability, availability, interest, patience and adaptability when the users interact with each other. These ratings were analysed using the fuzzy system to obtain the trustworthiness of the users. A fuzzy trust inference system has been used because fuzzy systems have the ability to deal with imprecise and uncertain information. Trust can be considered as a set of one or more personality characteristics. The proposed fuzzy system is extendable because in this system, trust can be defined as a set of one or more personality attributes. The attributes can also be expanded. The information extracted through the application of this proposed fuzzy system can be used in many issues related to social networks.

According to the results, all considered fuzzy systems have error mid less than 0.015 and among the FIS systems, FIS9 has the lowest error mid with 0.0014. Also, all considered fuzzy systems have an F-score greater than 0.86 and among FIS systems, FIS1-4 and FIS7-8 have achieved the highest F-score with 0.8835. Based on the results, the proposed fuzzy system shows an acceptable accuracy and it can be useful for evaluating the trustworthiness of users.

In future work, we can focus on developing and improving a set of fuzzy rules to make it more precise and accurate. The proposed approach can also be developed to be able to use more or different personality attributes as inputs of the fuzzy system.

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