Application of Intelligent Adaptive Neuro Fuzzy Method for Reusability of Component Based Software System

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Abstract: *Component Based Software System (CBSS) provides an easy and efficient way to develop new software application with the help of existing software components of similar functionalities. It increases the reusability of software components and reduce the development time, cost and effort of software developers. To select the appropriate component, it become essential to assess the reusability of software components so that suitable component can be selected to reuse in another application. For assessing the reusability of CBSS, several factors are required to be considered. In this paper, four reusability sub-factors Interface Complexity (IC), Understandability (Un), Customizability (Co) and Reliability (Re) are used as input variables and reusability is assessed using Fuzzy Inference System (FIS) and Adaptive Neuro Fuzzy Inference System (ANFIS) approach because these two approaches are commonly used approach for assessing the quality factors. For experimental work, one case study has been done where rules are generated to assess reusability using four different reusability factors by taking feedback from researchers and academicians using online survey. Reusability was assessed for ten different values of input variables. Experiment shows that results obtained from ANFIS method were closer to the original values. Root Mean Square Error (RMSE) of FIS results was 6.05% which was further reduced by the application of ANFIS approach and finally 2.20% of RMSE was achieved. This research work will be helpful for software developers and researchers to assess the reusability of software components and they will be able to take corrective decision for choosing the appropriate component to be reused in new software applications, which will reduce their effort, time and cost of development.*

Keywords: *Component, reusability, software, fuzzy, ANFIS, interface complexity, understandability, customizability, reliability.*

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1. Introduction

Component Based Software Engineering (CBSE) is a discipline for designing and constructing the software applications by using existing set of software components which are already tested. Cost effective software development is the main concern of the software industries for which they are adopting the concept of Component Based Software Development (CBSD). This approach improves the productivity and reduces the development time, cost and effort by reusing the existing software components. The concept of Component Based Software System (CBSS) is so popular and accepted among the software industries with the fact that a product will work properly if it has already worked before [10]. Reusability is described as the capability of previously developed software components to be used again or used repeatedly in part on it entirely, with or without modifications [4]. Reusability of software components provides large number of benefits to software industries and considered among one of the major factors to improve software productivity and quality. It was claimed that reusability of software components has reduced software development effort to 17-20%, development time to 70%, development cost up to 84% and increase the productivity index up to 26.2% [9]. Reusable components include generic code, procedures, subsystem, software requirement and design specifications [7]. It was observed that 53% of software projects performed reuse activities in more than 30% of their development process and 49% projects reused above 80% of their source code [19]. These benefits motivate reusability research which has been started in late 1960s and still continued [5]. Reusing the software components is not a simple task, for this software developers should select the appropriate software component to be reused. For this purpose, it is essential to assess the reusability of the software components. To assess the reusability, first task is to identify the appropriate reusability sub-factors. Reusability depends on several sub-factors which are described in different quality models and all have their importance. In most of the quality factor models, researchers have selected at least four sub-factors. So, in this research work, we have also selected four major reusability sub-factors, Interface Complexity (IC), Understandability (Un), Customizability (Co), and Reliability (Re). These four sub-factors are given as the most suitable reusability sub-factors from researcher's point of view [6] and feedback is also received about these sub-factors from the soft-ware developers. After selecting sub-factors next question arises that which technique should be used for assessing the reusability. For this purpose, we have selected soft computing techniques as it can be used to deal with the uncertain data or less data [31]. Reusability is real time issue, so soft computing techniques can be used effectively to assess the reusability of CBSS. Fuzzy and Adaptive Neuro Fuzzy Inference System (ANFIS) are two most important soft computing techniques. Fuzzy approach can work with uncertain data and in ANFIS approach, model can be trained using training data. In fuzzy approach, if-then rules are used based on the expert reviews and ANFIS approach combines the advantages of both fuzzy and Neural Network (NN) [39] approach to solve any problem. These techniques have been applied by many researchers to measure different quality attributes. The major objective of this research work is to evaluate the reusability of the software components, for which a fuzzy model is proposed. This fuzzy model is taking reusability sub-factors as input and reusability was generated as output. The results are compared with the original set of data which was collected from various software experts and researchers and error rate was generated. To reduce this error rate, the proposed fuzzy model was trained against the training data also and ANFIS approach was applied on the same input values to generate the output. The main contribution of this research paper is that it will help the software developers to assess the reusability of software components of similar functionalities, so that software developers can select the most reusable software component to be reused which will further improve the productivity, maintainability, and efficiency of the software applications. This research paper is organized into different sections: section 2 describes the literature review. Experimental work is defined in sections 3 and 4 is about result analysis followed by conclusion and future scope in section 5.

2. Literature Review

Reusability is the basic criterion for evaluating the performance of any component. The whole concept of CBSS fails if the software components are not reusable. Assessment of reusability for software components become essential to select the most suitable component of similar functionalities. Gill [9] describe the basic concepts of reusability, its importance, and related issues. A reusability model and set of metrics were given to assess the reusability of black box components based on three reusability sub-factors [38]. Reusability of any software component can be assessed by measuring its different sub-factors. These sub-factors are described in different component-based software models. The importance of reusable software components has been discussed and components are categorized into six different categories based on reusability aspects [10]. In 2007, several metrics were also explored to measure different aspects of component reusability [28]. Kaur *et al*. [16] have discussed the importance of component software to overcome the situation of software crisis and gave important information that how software developers can use their time efficiently by adopting the concept the CBSS. After those different methods were presented by researchers to assess the reusability of CBSS. Sandhu *et al*. [26] have compared three different approaches fuzzy, neuro-fuzzy and fuzzy-GA for reusability estimation and shows that fuzzy-GA algorithm provides more accurate results in comparison of other techniques. In 2009, different metrics were used to evaluate the reusability and independence of software component [32]. Sharma *et al*. [28] have proposed artificial neural net-work approach for reusability assessment and find put the results based on different numbers of neurons. In 2010, a set of reusability metrics were proposed to establish a relationship between those metrics and reusability of components. Experiment was performed using fuzzy approach to assess the reusability of different components [23]. After that an effective model was given to ass1ess the reusability of software components at design phase [21]. An exhaustive review on component quality was performed to focus on the importance of component reusability. This review shows that there is a large scope for exploring soft computing approaches for measuring different quality attribute [18]. A set of software metrics were given to measure the interconnection between the components which can further used to assess the reusability of CBSS [36]. Ravichandran *et al.* [25] have proposed an automation process for component selection using ANFIS approach based on 14 parameters and the results were validated using Fuzzy Weighted Relational Coefficient (FWRC). A software application to assess the different software components stored in the repository is also proposed in 2013. With the help of this application, it become convenient to access the component to be reused which further improves the productivity [39]. ANFIS approach was applied for reusability assessment based on four sub-factors and compare the results with fuzzy approach [17]. A literature review has been given on different techniques used for component reusability assessment and highlighted the major challenges related with each technique [20]. Goel and Sharma [12] have also applied ANFIS approach for predicting the reusability of software components based on three sub-factors and shows that ANFIS approach provides better results than Fuzzy approach. Singh *et al*. [30] have done a review on reusability of software components where they have discussed about different types of tools, components and metrics of software reusability. A systematic review on different reusability metrics was done by Thakral *et al*. [33]. They also identified the major attributes of reusability based on literature review a reusability-based quality framework was proposed for software component with component quality model for different stakeholders like users, managers and developers [34]. Tyagi and Sharma [37] have used fuzzy and ANFIS approach to evaluate the Re of CBSS and also compare the results. Agarwal *et al*. [1] have used fuzzy approach to measure the reusability of CBSS using bisector and centroid method and identify that centroid method was giving more consistent results in compared to bisector method. Ying *et al*. [40] have shown the importance of fuzzy method in learning structure, where they have proposed a deep feature mapping algorithm using fuzzy C-means. Jindal and Mittal [15] have proposed that coupling and cohesion are important for assessing the reusability of web-service software applications and provide a deep learning classification scheme for measuring these attributes. Negi and Tiwari [22] have used Random Forest Algorithm (RFA) to assess the reusability using Hidamber and Kemerer (CK) metrics for open-source object-oriented software and achieved 98.64% accuracy. Diamantopoulos and Symeonidis [6] have also applied different machine learning algorithms for giving reusability estimation models at both class and package levels and shows that these models can be effective for assessing reusability as perceived by developers. Thapar and Sarangal [35] have proposed a Fuzzy Analytical Hierarchy Process (FAHP) and quality, metrics for quantifying the reusability of software system and provides more acceptable results. ANFIS method was also used to assess the usability of CBSS and the results were compared with fuzzy method and it was found that ANFIS method provides better results when the nature of membership function was triangular [2]. To make the process simpler for finding reusability sub-factors and their metrics a review was done in 2021 [3]. From this literature review, it was observed that fuzzy and ANFIS approach has been used to assess different quality attributes of CBSS. Work has also been done on reusability of CBSS using software metrics, fuzzy approach. Singh and Tomar [29] have applied fuzzy approach for reusability assessment using five input factors. Godra and Sangwan [11] have also used five input variables and assessed reusability for five different input values. It has been also analyzed that there is lack of proper description of how Fuzzy and ANFIS approach have been applied and how the comparison has been done between fuzzy and ANFIS approach. In this paper, work has been done to evaluate the reusability of software component using fuzzy and Neuro fuzzy approach with proper description of research methodology and comparison is also done based on the error rate.

3. Experimental Work

From literature review, it is observed that Fuzzy and ANFIS approach has been used by different researchers for measuring different quality factors like usability, maintain-ability, reliability etc., which shows that reusability can also be assessed using these approaches. The complete procedure of this research work is shown in Figure 1.

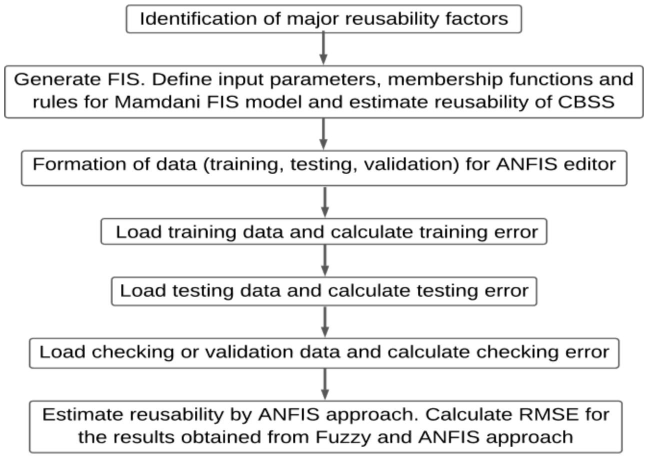

Figure 1. Proposed method for reusability evaluation.

- *Step* 1: Identification of Major Reusability Sub-Factors: from literature review, it was identified that there are many reusability sub-factors and different researchers have their own opinion about these sub-factors. In this paper, Inter-face Complexity (IC), Understandability (Un), Customizability (Co), and Reliability (Re) have been selected as major reusability factors for CBSS because in most of the quality factor models, developers have selected at least four sub- factors and these four sub-factors are given as the most suitable reusability sub-factors from researcher's point of view [6] and feedback is also received about these sub-factors from the software developers. These four sub-factors can be defined as:

  a) Interface Complexity (IC): the component interface complexity is the estimate of the complexity due to interfaces between components. It is inversely proportional to the reusability [31].
  b) Understandability (Un): it can be defined as the capability of the component to enable the user to understand whether it is suitable and how it can be used for tasks [14]. It depends on the functional description and the documentation of the component [7]. It is directly proportional to reusability.
  c) Customizability (Co): customizability is directly proportional to reusability. It is the ability of the component to be customized. It is required for the

component to be customizable for adjusting itself into specific requirements during integration process [27].

d) Reliability (Re): it is the probability that the system will perform as intended over a specified time interval [8]. The high reliability of a component increases the chances of high reusability of software components.

Based on these sub-factors reusability of any component can be given as:

$$Reusbc = fc(ICc, Unc, Coc, Rec) \quad (1)$$

Where f can be implemented using FIS and ANFIS approach in c MATLAB.

- *Step* 2: Generate Fuzzy Model: to assess the reusability of CBSS, four major reusability sub-factors IC, Un, Co, and Re are integrated as inputs for a Fuzzy Inference System (FIS). From two different types of FIS, Madami FIS is used in this work as it has output membership function and well suited for human input values. The proposed model is shown in Figure 2. To assess the reusability using this fuzzy model following steps are followed:

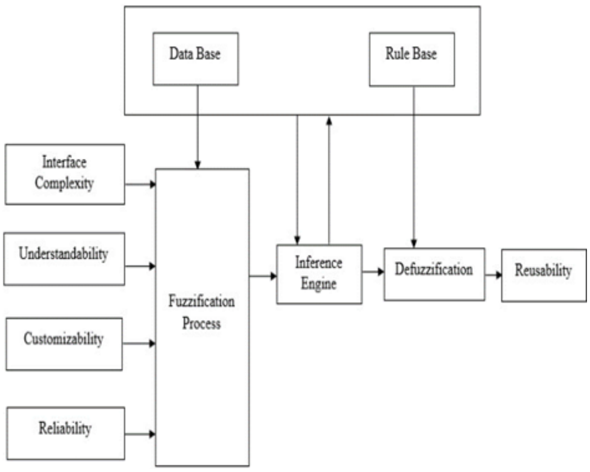

Figure 2. Fuzzy model for reusability of CBSS.

a) Define Input Parameters: four major reusability subfactors IC, Un, Co, and Re are taken as input parameters for fuzzy model and reusability is taken as output variable.

b) Define Membership Function: it is a function that specifies the degree to which a given input belongs to a set. Three membership functions (low, medium and high) were defined for all the inputs and five membership functions (very low, low, medium, high and very high) were used for the output variable (reusability). The membership function was triangular in nature because it is a straight-line curve which can be calculated easily in lesser time, and it is mostly referred by researchers for evaluation of different quality aspects. It was also analyzed that triangular membership function provides immediate solutions to the optimization problems in fuzzy models [24]. Figure 3 shows the membership function for input variable IC and Figure 4 shows the membership function for reusability.

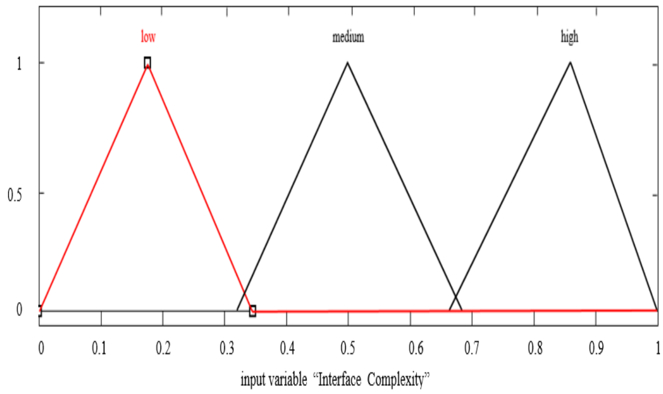

Figure 3. Membership function for IC.

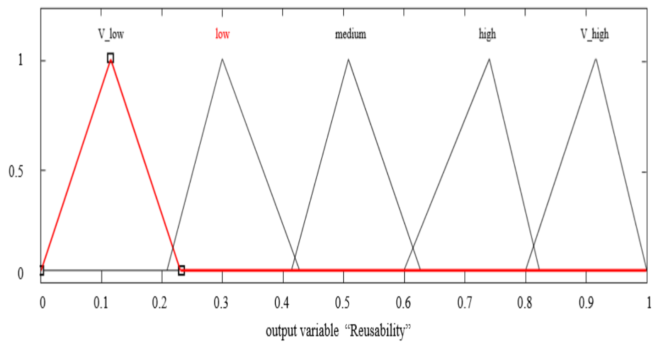

Figure 4. Membership function for reusability.

c) Create Rule Base: a rule base was created based on the feedback of different CBSS developers and researchers. For collecting the feedback, a survey form was created which was having information about reusability sub-factors along with their importance. To create rule base, reusability sub-factors can have three values, low, medium or high. Based on these values, reusability can be very_low, low, medium, high or very_high. This survey form was shared among academicians, researchers and professionals who are working on CBSS to collect the responses. There is total 4 input variables with three membership function, so total (3^4) 81 rules can be generated. This survey form and rule base is uploaded on GitHub so that researchers working in this area can be benefited in future [13]. There is total 4 input variables with three membership function, so total (3^4) 81 rules are generated. Some of the of the rules are:

- Rule 1: (if interface complexity is high) and (if understandability is high) and (if customizability is high) and (if reliability is high) then reusability is very high.
- Rule 13: (if interface complexity is medium) and (if understandability is high) and (if customizability is medium) and (if reusability is high) then reusability is high.

These rules are feed into fuzzy inference engine and inputs are fuzzified. For fuzzification of input variables, Intuition method is used. This method is based upon the human experience and intelligence. Each curve is a membership function corresponding to various fuzzy variables like low, medium and high.

d) Estimation of Reusability Using Fuzzy Model: after that reusability was assessed for 10 different inputs values (based on membership functions and rule base). For defuzzification, Center Of Gravity (COG) method is used. The defuzzified value x^* using COG method can be given as:

$$x* = \frac{\int x\mu a\,(x)dx}{\int \mu a\,(x)dx} \tag{2}$$

Assessed value of reusability is given in results section as Table 1.

Table 1. Reusability value obtained from fuzzy model.

S.No	Inputs				Output (Reusability)
	IC	Un	Co	Re	
1	0.15	0.16	0.35	0.52	0.403
2	0.241	0.25	0.231	0.26	0.311
3	0.323	0.35	0.367	0.39	0.417
4	0.29	0.3	0.32	0.28	0.313
5	0.42	0.41	0.426	0.412	0.514
6	0.19	0.56	0.41	0.89	0.716
7	0.35	0.71	0.79	0.81	0.605
8	0.62	0.215	0.53	0.39	0.469
9	0.69	0.66	0.31	0.28	0.119
10	0.38	0.83	0.68	0.9	0.712

- *Step* 3: Adaptive Neuro Fuzzy approach (ANF) to Assess Reusability of CBSS: this approach adopts and integrate the advantages of both Fuzzy System (FS) and NN approaches in a hybrid system. It provides knowledge representation and smoothness because of Fuzzy nature and have learning ability and adaptability due to NN [2]. ANFIS architecture is shown in Figure 5.

For any two input variables x1 and x2, fuzzy rule base for ANFIS can be summarized as:

- Rule 1: if x is $A1$ and y is $B1$ then $f1=P1x+Q1\,y+R1$
- Rule 2: if x is $A2$ and y is $B2$ then $f2=P2x+Q2\,y+R2$

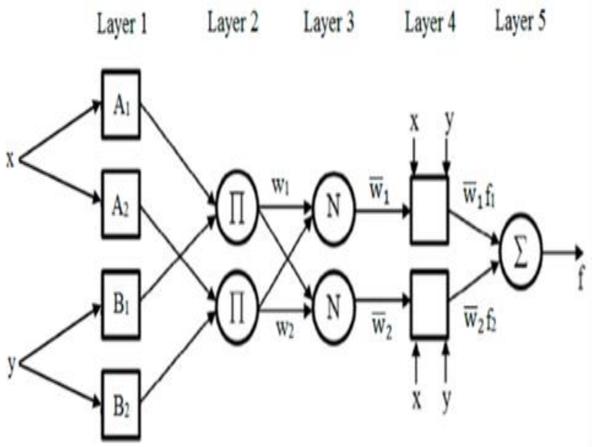

Figure 5. ANFIS architecture.

a) Formation of Training, Testing and Validation Data: for using ANFIS approach training, testing and validation data are required. Data set was collected from academicians, researchers and CBSS developers using online survey form which was having details about reusability sub-factors and rule base. In total we have gathered total 129 responses from which we have used 114 responses because rest of the data was incomplete. From this data set 80% of the data is used as training data and rest 20% is used as testing data. For validation of the results, validation (checking) data is gathered separately [13].

- *Step* 4: Loading Training Data and Calculate Training Error: after collecting the data, training, testing, and checking data is loaded and fuzzy model is trained against the training data using backpropagation method. At the end of the training process the value of training error was 0.0586, which is shown in Figure 6.

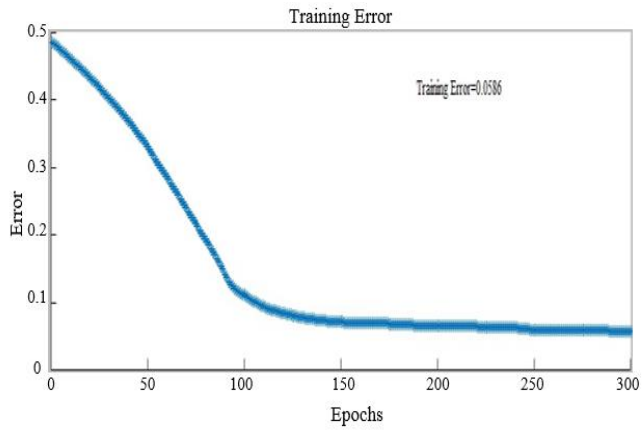

Figure 6. Training error.

- *Step* 5: Calculate Testing Error: after training the model, testing data was used to calculate the testing error and at the end of testing process, the value of testing error was 0.079 as shown in Figure 7.

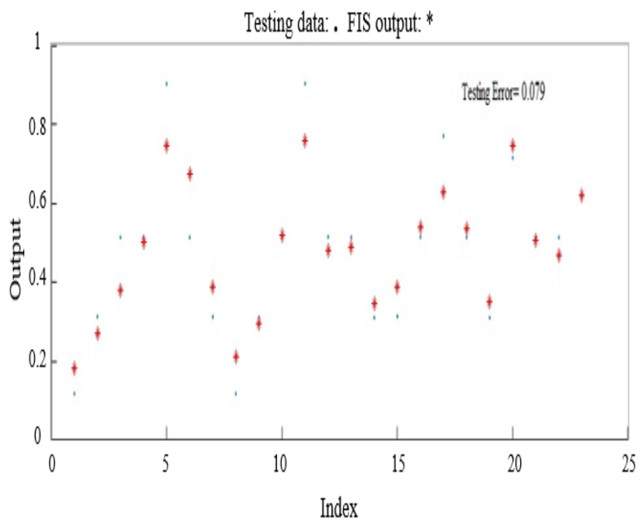

Figure 7. Testing error.

- *Step* 6: Calculate Checking Error: for validation of the model, checking data is loaded, and error was calculated. At the end of the validation process the value of validation (checking) error was 0.063 which is shown in Figure 8.

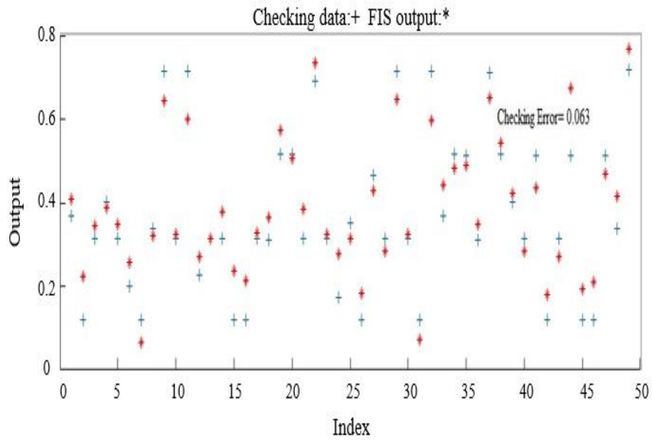

Figure 8. Checking error.

- *Step* 7: Reusability Assessment Using ANFIS Method: after developing the ANFIS model, reusability was calculated for same input values as fuzzy model which is given in results section as Table 2.

Table 2. Reusability value obtained from ANFIS model.

S.No	Inputs				Output
	IC	Un	Co	Re	(Reusability)
1	0.15	0.16	0.35	0.52	0.39
2	0.241	0.25	0.231	0.26	0.282
3	0.323	0.35	0.367	0.39	0.443
4	0.29	0.3	0.32	0.28	0.293
5	0.42	0.41	0.426	0.412	0.527
6	0.19	0.56	0.41	0.89	0.748
7	0.35	0.71	0.79	0.81	0.579
8	0.62	0.215	0.53	0.39	0.295
9	0.69	0.66	0.31	0.28	0.206
10	0.38	0.83	0.68	0.9	0.579

4. Result Analysis

In this research work, reusability of CBSS were analyzed using Fuzzy and ANFIS methods which is shown in Tables 1 and 2 respectively. Experimental results obtained from both the approaches were analyzed and compared with the original data. To find out the accuracy level of the experimental work, Root Mean Square Error (RMSE) was calculated.

$$RMSE = (((E - O)^2)/N) * 100 \quad (3)$$

Where *E* is the experimental output and *O* is the original output. This comparison is shown in Table 3.

From the results, it was analyzed that result obtained from Fuzzy model was having RMSE of 6.05%. In case of ANFIS method, RMSE was 2.20%, which is a significant error reduction. A graph was also generated for showing the reusability values obtained from Fuzzy and ANFIS method against the original values, which is shown in Figure 9. From this figure, it is clear that the graph for ANFIS results is much closer to the graph of original values as the results obtained from ANFIS method were closer to original values. Thus, in this research work reusability of CBSS was evaluated using two different soft computing approaches (fuzzy and ANFIS) and error rate was also reduced by training the fuzzy model.

Table 3. Comparison of FIS and ANFIS results.

Original output (O)	FIS output (F)	ANFIS output (A)	(F − O)	(A − O)	$(F - O)^2$	$(A - O)^2$
0.36	0.403	0.39	0.043	0.03	0.001849	0.0009
0.3	0.311	0.282	0.011	-0.018	0.000121	0.000324
0.45	0.417	0.443	-0.033	-0.007	0.001089	4.90E-05
0.25	0.313	0.293	0.063	0.043	0.003969	0.001849
0.56	0.514	0.527	-0.046	-0.033	0.002116	0.001089
0.73	0.716	0.748	-0.014	0.018	0.000196	0.000324
0.59	0.605	0.579	0.015	-0.011	0.000225	0.000121
0.39	0.469	0.295	0.079	-0.095	0.006241	0.009025
0.18	0.119	0.206	-0.061	0.026	0.003721	0.000676
0.6	0.712	0.579	0.112	-0.021	0.012544	0.000441
					RMSE=6.05%	RMSE=2.20%

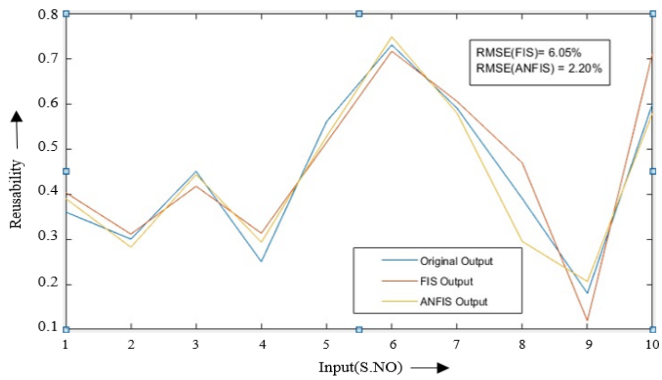

Figure 9. Analysis of results obtained from fuzzy and ANFIS method.

5. Conclusions and Future Scope

For CBSS, reusability is one of the most important factors and it is required to measure the reusability of different components to select the most suitable component. This research work is an attempt to assess the reusability of CBSS using two different soft computing techniques, i.e., fuzzy, and ANF. Soft computing techniques are useful for solving the problems, for which mathematical models are not available. This is the reason that soft computing approaches are best suitable for measuring the qualitative features of any software. Fuzzy approach has the advantage of working with uncertain on incomplete data and ANFIS approach has the advantages of both Fuzzy as well as of NNs. Reusability depends on different sub-factors. For this work, IC, Un, Co, and Re were used. Using these sub-factors, fuzzy model was developed, and reusability was assessed for ten different input values and after that ANFIS approach was also used to assess the reusability for the same input values by training the fuzzy model. After training the model, training, testing, checking error was calculated. Results obtained from both the approaches were compared based on the RMSE and it was identified that ANFIS approach reduces the error rate in comparison to fuzzy model. This research work will be useful for the software developers to assess the reusability of different components of any CBSS, so that suitable component can be selected for reusing in other applications which will further reduce development time, cost and effort of software development. The limitation of this work is that we have used four reusability factors which were defined as most critical reusability factors by most of the researchers but in future other relevant factors can also be used. In future, similar work can also be done using more number of reusability factors and results can be compared. Another limitation of this research work is the data set but in future results can be obtained for larger dataset also. In future, similar work can also be done using another existing method like Genetic Algorithms (GA), NNs etc., and results can be compared.

References

[1] Agarwal J., Dubey S., and Tiwari R., "Proposal and Validation of Usability Model for Component Based Software System," *Engineering Journal*, vol. 21, no. 5, pp. 243-255, 2017. DOI: https://doi.org/10.4186/ej.2017.21.5.243

[2] Agarwal J., Dubey S., and Tiwari R., "Usability Estimation of Component-based Software System Using Adaptive Neuro Fuzzy Approach," *International Journal of Advanced Intelligence Paradigms*, vol. 22, no. 1-2, pp. 99-113, 2022. https://doi.org/10.1504/IJAIP.2022.123018

[3] Agarwal J. and Kumar M., "Software Metrics for Reusability of Component Based Software System: A Review," *The International Arab Journal of Information Technology*, vol. 18, no. 3, pp. 319-325, 2021. https://doi.org/10.34028/iajit/18/3/8

[4] Ampatzoglou A., Kritikos A., Kakarontzas G., and Stamelos I., "An Empirical Investigation on the Reusability of Design Patterns and Software Packages," *Journal of Systems and Software*, vol. 84, no. 12, pp. 2265-2283, 2011. https://doi.org/10.1016/j.jss.2011.06.047

[5] Beydoun G., Hoffmann A., Garcia R., Shen J., and Gill A., "Towards an Assessment Framework of Reuse: A Knowledge-level Analysis Approach," *Complex and Intelligent Systems*, vol. 6, pp. 87-95, 2020. https://doi.org/10.1007/s40747-019-0116-1

[6] Diamantopoulos T. and Symeonidis A., *Assessing the Reusability of Source Code Components*, Springer, 2020. https://doi.org/10.1007/978-3-030-30106-4_10

[7] Gao J., "Component Testability and Component Testing Challenges," *in Proceedings of the International Workshop on Component-based Software Engineering,* San Jose, pp. 1-6, 2000. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a224cc94581c74e1d991a0d233ad47da7027ac81

[8] Geraci A., Katki F., McMonegal L., and Meyer B., *IEEE Standard Computer Dictionary: Compilation of IEEE Standard Computer Glossaries*, IEEE Press, 1991. https://dl.acm.org/doi/10.5555/574566

[9] Gill N., "Reusability Issues in Component-based Development," *ACM SIGSOFT Software Engineering Notes*, vol. 28, no. 4, pp. 1-4, 2003. https://doi.org/10.1145/882240.882255

[10] Gill N., "Importance of Software Component Characterization for Better Software Reusability," *ACM SIGSOFT Software Engineering Notes*, vol. 31, no. 1, pp. 1-3, 2006. DOI:10.1145/1108768.1108771

[11] Godara D. and Sangwan O., "Neuro-fuzzy Based Approach to Software Reusability Estimation," *IJCTA, International Science Press*, vol. 9, pp. 3811-3891, 2016. https://www.researchgate.net/publication/312225864_Neuro_fuzzy_based_approach_to_software_reusability_estimation

[12] Goel S. and Sharma A., "Neuro Fuzzy based Approach to Predict Component's Reusability," *International Journal of Computer Applications*, vol. 106, no. 5, pp. 33-38, 2014. https://www.researchgate.net/publication/321097131

[13] https://github.com/wssmanojkumar/SENGDATA.git, Last Visited: 2023.

[14] ISO/IEC 9126: Software Engineering-Product Quality-Part 1: Quality, "Model. International Organization for Standardization and International Electrotechnical Commission,"

[15] Jindal R. and Mittal S., "Software Reusability Metrics Estimation for Improving Stability by Clustering Base Convolution Neural Network," *Materials Today: Proceedings*, 2020. https://doi.org/10.1016/j.matpr.2020.09.615

[16] Kaur K., Kaur P., Bedi J., and Singh H., "Towards a Suitable and Systematic Approach for Component Based Software Development," *International Journal of Computer and Information Engineering*, vol. 1, no. 3, pp. 609-612, 2007. https://zenodo.org/record/1055038

[17] Kumar V., Sharma A., Kumar R., and Grover P., "Quality Aspects for Component-Based Systems: A Metrics-Based Approach," *Journal of Software: Practices and Experience*, vol. 42, no. 2, pp. 1531-1548, 2012. https://doi.org/10.1002/spe.1153

[18] Kumar V., Kumar R., and Sharma A., "Applying Neuro-fuzzy Approach to Build the Reusability Assessment Framework across Soft-ware Component Releases - An Empirical Evaluation," *International Journal of Computer Applications*, vol. 70, no. 15, pp. 41-47, 2013. DOI:10.5120/12041-8047

[19] Mohagheghi P., The Impact of Software Reuse and Incremental Development on the Quality of Large Systems, Doctoral Thesis, Norwegian University of Science and Technology, 2004. http://hdl.handle.net/11250/249882

[20] Mohan N., Kaur I., Kaur M., and Verma A., "Component Reusability for Component Based Software Engineering," *International Journal of Computer Science Technology*, vol. 4, no. 1, pp. 53-56, 2013. https://www.researchgate.net/publication/275028645_Component_Reusability_for_Component_Based_Software_Engineering

[21] Nair T. and Selvarani R., "Estimation of Software Reusability: An Engineering Approach," *ACM SIGSOFT Software Engineering Notes*, vol. 35, no. 1, pp. 1-6, 2010. https://doi.org/10.1145/1668862.1668868

[22] Negi P. and Tiwari U., "Machine Learning Algorithm for Assessing Reusability in Component Based Software Development," *Easy Chair Reprint*, vol. 4142, pp. 1-8, 2020. https://easychair.org/publications/preprint/TLm5

[23] Nerurkar N., Sharma A., and Sagar S., "A Soft Computing Based Approach to Estimate Reusability of Software Components," *ACM SIGSOFT Software Engineering Notes*, vol. 35, no. 4, pp. 1-4, 2010. https://doi.org/10.1145/1811226.1811235

[24] Pedrycz W., "Why Triangular Membership Functions?," *Fuzzy Sets Systems*, vol. 64, no. 1, pp. 21-30, 1994. https://doi.org/10.1016/0165-0114(94)90003-5

[25] Ravichandran K., Suresh P., and Sekr K., "ANFIS Approach for Optimal Selection of Reusable Components," *Research Journal of Applied Sciences Engineering and Technology*, vol. 4, no. 24, pp. 5304-5312, 2012. https://www.researchgate.net/publication/269301413_Corresponding_Author_ANFIS_Approach_for_Optimal_Selection_of_Reusable_Components

[26] Sandhu P., Salaria D., and Singh H., "A Comparative Analysis of Fuzzy, Neuro-Fuzzy and Fuzzy-GA Based Approaches for Software Reusability Evaluation," *Worlds Academy of Science, Engineering and Technology*, vol. 2, no. 2, pp. 693-696, 2008. DOI: doi.org/10.5281/zenodo.1085750

[27] Sharma A., Kumar R., and Grover P., "Critical Survey of Reusability Aspects for Software Components," *in Proceedings of the World Academy of Science, Engineering and Technology*, Bangkok, Thai-land, pp. 419-424, 2007.

[28] Sharma A., Grover P., and Kumar R., "Reusability Assessment of Software Components," *ACM SIGSOFT Software Engineering Notes*, vol. 34, no. 2, pp. 1-6, 2009. https://doi.org/10.1145/1507195.1507215

[29] Singh A. and Tomar P., "Estimation of Component Reusability through Reusability Metrics," *International Journal of Computer and Information Engineering*, vol. 8, no. 11, pp. 2018-2025, 2014. DOI: doi.org/10.5281/zenodo.1097333

[30] Singh C., Pratap A., and Singhal A., "An Estimation of Software Reusability using Fuzzy Logic Techniques," *in Proceedings of the International Conference on Signal Propagation and Computer Technology*, Ajmer, pp. 250-256, 2014. DOI: 10.1109/ICSPCT.2014.6884890

[31] Singh S., Thapa M., Singh S., and Singh G., "Software Engineering-Survey of Reusability Based on Software Component," *International Journal of Computer Applications*, vol. 8, no. 12, pp. 39-42, 2010. DOI:10.5120/1339-1736

[32] Suri P. and Garg N., "Software Reuse Metrics: Measuring Component Independence and its Applicability in Software Reuse," *International Journal of Computer Science and Network Security*, vol. 9, no. 5, pp. 237-248, 2009. http://paper.ijcsns.org/07_book/200905/20090532.pdf

[33] Thakral S., Sagar S., and Vinay S., "Reusability in Component Based Software Development-A Review," *World Applied Sciences Journal*, vol. 31, no. 12, pp. 2068-2072, 2014. DOI: 10.5829/idosi.wasj.2014.31.12.671

[34] Thapar S., Singh P., and Rani S., "Reusability-based Quality Framework for Software Components," *ACM SIGSOFT Soft-ware Engineering Notes*, vol. 39, no. 2, pp. 1-5, 2014. https://doi.org/10.1145/2579281.2579298

[35] Thapar S. and Sarangal H., "Quantifying Reusability of Software Components Using Hybrid Fuzzy Analytical Hierarchy Process (FAHP)-Metrics Approach," *Applied Soft Computing*, vol. 88, pp. 105997, 2020. https://doi.org/10.1016/j.asoc.2019.105997

[36] Trivedi P. and Kumar R., "Software Metrics to Estimate Software Quality Using Software Component Reusability," *International Journal of Computer Science Issues*, vol. 9, no. 2, pp. 144-149, 2012. https://www.researchgate.net/publication/267383149_Software_Metrics_to_Estimate_Software_Quality_using_Software_Component_Reusability

[37] Tyagi K. and Sharma A., "An Adaptive Neuro Fuzzy Model for Estimating the Reliability of Component-based Software Systems," *Applied Computing and Informatics*, vol. 10, no. 1-2, pp. 38-51, 2014. https://doi.org/10.1016/j.aci.2014.04.002

[38] Washizaki H., Yamamoto H., and Fukazawa Y.,"A Metrics Suite for Measuring Reusability of

Software Components," *in Proceedings of the 5th International Workshop on Enterprise Networking and Computing in Healthcare Industry*, Sydney, pp. 211-223, 2003. DOI: 10.1109/METRIC.2003.1232469

[39] Yasir N., Jamil B., and Ferzund J., "PDCML: A Model for Enhancing Software Reusability," *International Journal of Software Engineering and Its Applications*, vol. 7, no. 1, pp. 123-136, 2013. https://www.researchgate.net/publication/290545743

[40] Ying W., Wang J., Deng Z., Zhang F., and Li Z., "Fuzzy Clustering with Self-growing Net," *International Journal of Fuzzy Systems*, vol. 22, no. 8, pp. 450-460, 2020. DOI:10.1007/s40815-019-00782-z

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