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Neuro-Fuzzy Based Approach to Software Reusability Estimation

Deepika* and O.P. Sangwan**

Abstract : Software reusability is a quality attribute in which new software or its module is used with or without little modification. In this paper we have proposed a model based on five parameters: Understandability, Interface Complexity, Portability, Maintainability, and Customizability for accessing the level of reusability using Neuro-Fuzzy technique. The proposed model using ANFIS (Adaptive Neuro Fuzzy Inference System) is trained well and predicts satisfactory results with average training error 0.0221 and average testing error 0.04836, using hybrid as optimization method.

Keywords : Software reusability, Understandability, Interface Complexity, Portability, Maintainability, Customizability, Neuro-Fuzzy.

1. INTRODUCTION

Software reusability is a quality attribute, which measures the ease with which we can use the previously acquired concepts in new situations. It gives the extent that how much a particular software component is reusable. The estimation of software reusability is done on the basis of factors affecting reusability [1]. In order to select the important factors affecting reusability different papers which taken into account the different factors of reusability were selected and out of that five most important factors were selected in order to estimate the reusability. Different researchers used different techniques in order to estimate the level of reusability on the basis of the factors they have taken into consideration. In this paper, we have discussed about the factors used by various researchers for software reusability estimation. We have proposed a neuro-fuzzy model to estimate software reusability level on the basis of five parameters: Understandability, Interface Complexity, Portability, Maintainability, and Customizability.

This paper is organized as follows: Section II summarizes related work to predict software reusability, Section III describes the factors used, Section IV elaborates the proposed ANFIS approach, Section V shows experimental design, Section VI explain the results, conclusion and future scope is presented in section VII.

2. RELATED WORK

In order to measure reusability one has to consider the factors that affect reusability. Different researchers have taken into account different factors to measure reusability and used different soft computing techniques to measure the level of reusability. Sangwan *et al.* [2] proposed a model based on four parameters *i.e.*, changeability, understandability, documentation quality, and interface complexity of software for assessing software reusability level using soft computing techniques. In order to predict the level of reusability they used fuzzy model, neural network model and neuro-fuzzy model. The study shows that soft computing techniques can efficiently predict the reusability level and neuro-fuzzy model can be further extended as cost estimation model and for quality prediction. Neuro-Fuzzy approach was used by Kumar *et al.* [3] in order to predict reusability of software components and

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a framework for component reusability management in software component intermediate release was also proposed and concluded that neuro-fuzzy gives better result than standalone FIS or ANN and helps maintain the better software product quality and resource management across releases.

A fuzzy logic model was proposed by Singh *et al.* [4] based on five parameters to predict the level of reusability. Reusability has been discussed in terms of component based development and also proposed reusability metrics for components. The study shows that fuzzy logic resulted in better understanding of the reuse task and to estimate the development efforts. Singh *et al.* [5] introduced various metrics and estimate reusability using fuzzy logic approach for aspect oriented software. They have taken into account four metrics SoC, coupling, and cohesion, size metrics that affect software reusability in aspect oriented software and concluded that proposed model based on fuzzy will help software developer select best quality of software in term of reusability among aspect oriented software.

Object oriented metrics was presented by Amin *et al*. [12] to measure the factors affecting reusability. Factors that were taken into consideration were flexibility, maintainability, portability, documentation, stability, understandability, usage history, variability, and scope coverage and determined the correlation between these different factors of reusability. Three metrics were proposed by Goel and Sharma [8] *i.e*., coupling, complexity, and portability to check the level of reusability using Neuro-Fuzzy approach and results shows that Artificial Neuro Fuzzy Inference System (ANFIS) model was appropriate for assessing the reusability of components.

3. FACTORS USED

Table 1. Factors Affecting Software Reusability

Authors / Factors	Charu Singh et al. [4]	Dandashi et al. [11]	Fazal-e-Amin et al. [12]	Goel and Sharma [8]	Jeffery S. Poulin [10]	Kumar et al. [3]	Sagar et al. [6]	Sangwan et al. [2]	Singh and Tomar [16]	Singh et al. [5]	Paliwal et al. [13]	Sandhu Et al. [7]	Suri And Garg [15]	Subedha and Sridhar [9]	Shraddha et al. [14]
SoC										*					
Cohesion					*					*					
Coupling				*	*					*		*			
Size Complexity															
Interface Complexity	*			*											*
Portability			*	*	*	*	*								
Changeability								*							
Understandability		*	*		*	*		*	*		*				
Documentation Quality			*				*	*							

Customizability						*	*		*						*
Modularity	*														
Maintainability	*	*	*					*							
Flexibility	*		*												
Adaptability	*	*						*							*
Completeness		*			*										
Scope Coverage			*												
Stability			*												
Usage History			*												
Variability			*												
Error and Exception Handling					*										
Information Hiding					*										
Reliability					*				*						
Availability															*
Volume												*			
Regularity												*			
Reuse Frequency												*			
Usefulness													*		
Cost													*		
Quality													*		
Coverage Analysis														*	
Time														*	
Functional Usefulness														*	

Based on the study of different research papers as shown in Table 1, we have identified five most important factors widely used by various researchers which affect software reusability namely: Understandability, Interface Complexity, Portability, Maintainability, and Customizability. The details of these factors are as follows:

Understandability : It gives us the efforts needed to recognize the concept behind a software component. The higher the understandability the better will be the reusability.

Interface Complexity : The nature of components can be treated as black box, the source code may or may not be available, and application can interact with these components only with the help of well-defined interfaces with less complexity as much as possible. For better reusability the interface complexity should be low.

Portability : It is the ability of a component to be transferred from one location to another with little or no modification. The component should have high portability for better reusability.

Maintainability : It is the ease of modifying, correcting faults, and improving performance, and adapting to changed environments. For better reusability maintainability should be more.

Customizability : It is the ease of modifying according to customer's individual requirements. If customizability is upto expectation then the reusability of the components will be more and it will be easily maintained for future releases. These factors are selected on the basis of following table:

4. PROPOSED ANFIS APPROACH

The proposed Neuro-Fuzzy system is build, trained, and tested in MATLAB (Fig 1) and following steps is followed in this approach:

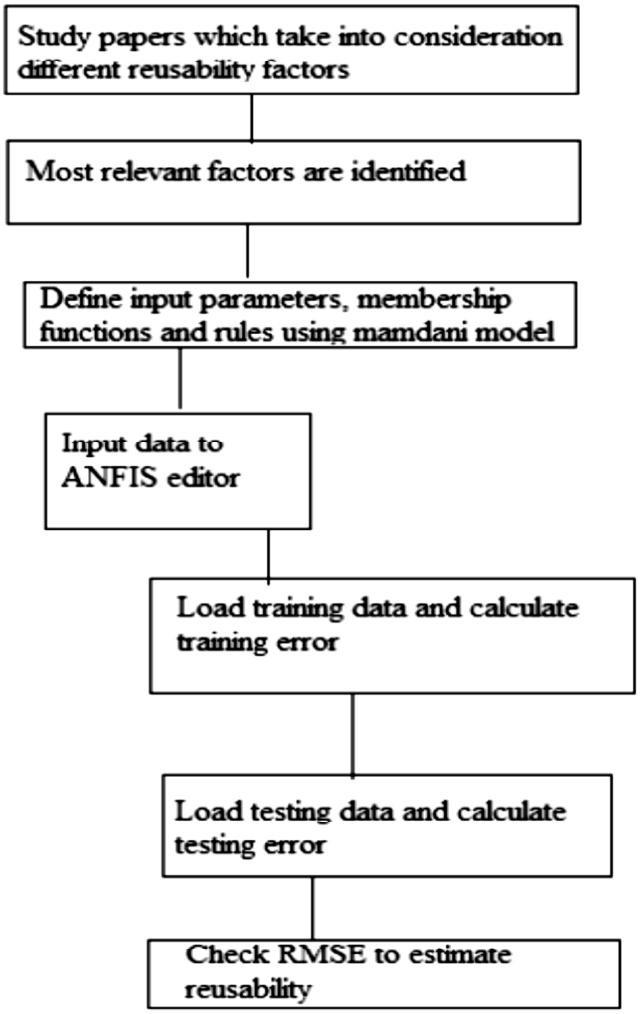

Fig. 1. Proposed Approach.

- To study different papers which take into account different reusability factors.
- To select the most important factors affecting reusability.
- Define membership functions and rules of input variables using mamdani system.
- For each input variable membership functions (low, medium, high) is determined.
- For each output variable membership functions (very low, low, medium, high, and very high) is determined.
- Fuzzy rules are generated in mamdani fuzzy inference system (FIS) on the basis of input variables and membership functions.
- On the basis of fuzzy rules, the training data, and testing data for ANFIS editor is evaluated.
- Using training and testing data, training and testing error is evaluated.

5. EXPERIMENTAL DESIGN

In proposed model for reusability, the input variables taken are understandability, interface complexity, portability, maintainability, and customizability. Each of these consists of fuzzy sets low, medium, and high. Membership function used is triangular membership function (trimf) and fuzzification process is applied on these sets by taking normalized values of these attributes. The output is reusability, consisting of five fuzzy sets very low, low, medium, high, and very high. The given ANFIS system contains 243 rules, 5 inputs and single output. The dataset for reusability is referred as training data and testing data. Upon training, the training error will be shown by the ANFIS which reflects how good the mapping function is working. Testing data will be used to validate the model and to check how ANFIS behaves for known data. The Fuzzy Inference System used for our model is of Mamdani-type and generated using Grid Partioning method. The number of datasets used for training is 100 and dataset used for testing is 50.

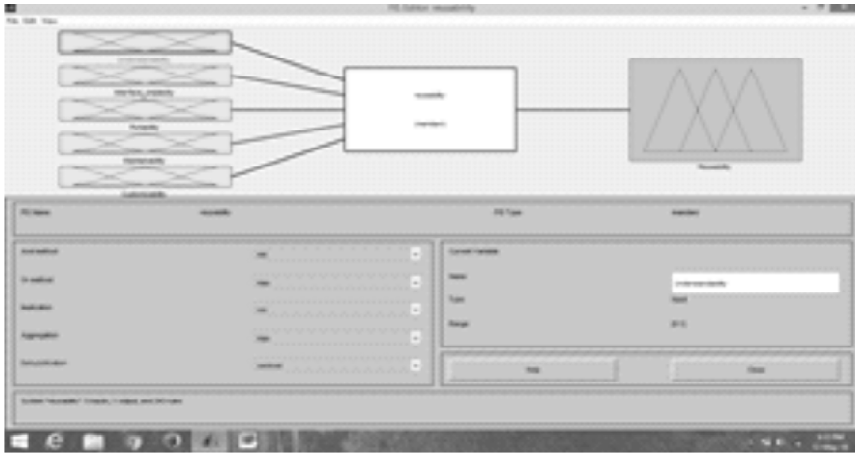

Fig. 2. Software Reusability Model with 5 inputs, 1 output, and 243 rules

Fig. 3. Membership Function Editor for Input Variable

Fig. 4. Membership Function Editor for Output Variable

Fig. 5. Rule Editor

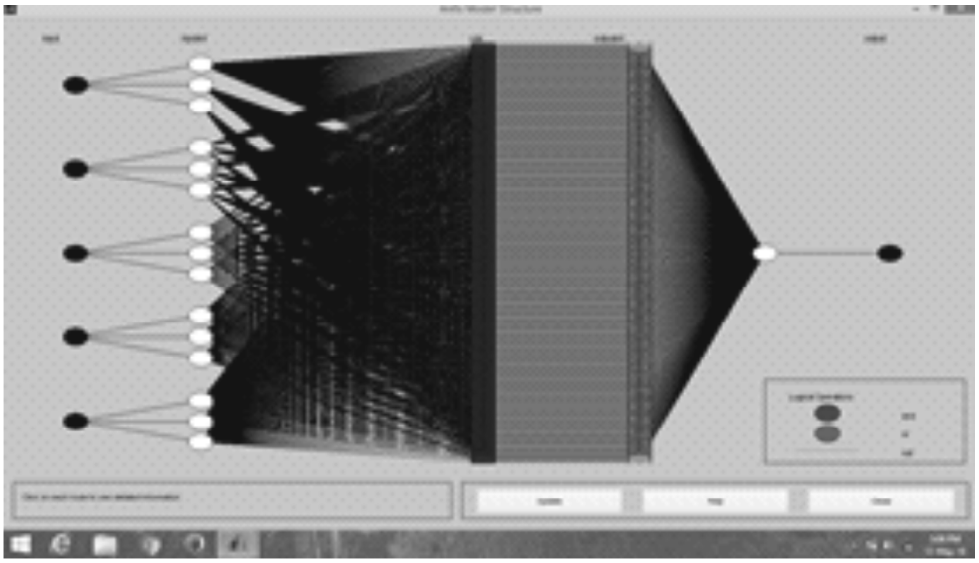

Fig. 6. FIS Structure

Fig. 7. Rule Viewer

Fig. 8. Average Training Error

Fig. 9. Average Testing Error

Table 2. Experimental Results

Rule #	*Understandability*	*Interface Complexity*	*Portability*	*Customizability*	*Maintainability*	*Reusability*
1.	0.3(L)	0.6(H)	0.54(M)	0.3(L)	0.6(H)	0.3(L)
2.	0.35(L)	0.575(M)	0.32(L)	0.29(L)	0.3(L)	0.314(L)
3.	0.5(M)	0.5(M)	0.5(M)	0.5(M)	0.5(M)	0.5(M)
4.	0.6(H)	0.4(M)	0.7(H)	0.8(H)	0.9(M)	0.7(H)
5.	0.87(H)	0.15(L)	0.63(H)	0.7(H)	0.9(H)	0.811(VH)

Table 2 shows results for some rules for different values of input variables used and value of reusability achieved.Defuzzification:Defuzzification is a process in which fuzzy values are converted into crisp quantities. Different methods used for defuzzification are centroid method, middle of maximum, smallest of maximum, largest of maximum, or weight average method etc.

The most commonly used method is centroid method and has large applicability. It is also called Center of Gravity or Center of Area. The defuzzified output for z^* is by (1) and validated for rule number 1, 3 and 4 from table 2.

$$z^* = \int \mu_C(z).z\, dz / \int \mu_C(z) dz \quad (1)$$

Where $\int$ denotes an algebraic integration.

$z^* = 0.341$ (for rule 1)

$z^* = 0.476$ (for rule 3)

$z^* = 0.696$ (for rule 4)

6. RESULTS

The average training error is 0.0221 given the number of epochs is 100 using Hybrid as optimization method. The average testing error after validation of training data comes out to be 0.04836 when error tolerance is 0. The rules designed are based on domain knowledge and the result is verified for the rules using Centroid as defuzzification method. The result shows that ANFIS model is appropriate for estimating the level of reusability and will help a software developer in selecting better quality of software in terms of reusability.

7. CONCLUSION AND FUTURE SCOPE

We have proposed soft computing technique *i.e.* Neuro-Fuzzy technique, to estimate level of reusability i.e. very low, low, medium, high, very high. MATLAB is used for our proposed work and ANFIS tool is used to train and validate the model. Five important variables that affect software reusability namely understandability, Interface complexity, portability, customizability, and maintainability were identified. On the basis of input variables, 243 rules are designed in the system and output reusability is tested with respect to the five input variables used. The rules designed are based on domain knowledge and the result is verified for the rules using Centroid as defuzzification method. The average training error is 0.0221 given the number of epochs is 100 using Hybrid as optimization method. The average testing error after validation of training data comes out to be 0.04836 when error tolerance is 0. We have used Neuro-Fuzzy technique as it combines the benefit of both neural network and fuzzy lozic and it is concluded that proposed ANFIS model can help the software developer in selecting better quality of software in terms of reusability. In future, apart from Neuro-Fuzzy technique other soft computing techniques like Support Vector Machine (SVM) can also be taken into consideration for the assessment of reusability of software components.

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