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Effort Estimation of Software Maintainability Using Soft Computing Techniques: a Critical Literature Survey

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Abstract: Maintainability is an essential quality aspect to promote the efficient software system. To develop the quality software and enhance the maintainability, the Component based system and object oriented techniques are used. In this literature review various soft computing approaches(Fuzzy Inference Systems, Artificial Neural Networks, Machine Learning, Train Neural Network, Fuzzy Layered approach and Adaptive Neuro-Fuzzy Inference Systems) are compare and assess to achieve the effort estimation of software maintainability. This literature survey indicates the soft computing techniques are very much applicable to predict software maintainability and gives satisfactory result.

Key words: Maintainability · Feedforward Backpropagation Neural Network · ANFIS · FIS · Machine Learning · Parameters

INTRODUCTION

Maintainability is the process of finding and correcting errors within a time stamp under specified resource. It is very helpful in increasing efficiency of the software by making some changes. In the field of software engineering, the maintainability is become very essential and that matters of growing importance for many companies. Many problems in software maintenance result from in sufficient practices in software development as solving errors, bugs, any kind of problem, implementing changes, impact analysis, testing and integration with other systems. In traditional software mean time of the repair is calculated that mean time is use to effect the change. Based on the survey, we analyze that basically maintenance activity is based on Size, Complexity, System user/customer, Operating Procedure, Maintenance Procedure, Environment Facilities, Maintenance Team and Documentation of Software.

Prominence in the present work to forecast maintainability, there are some factors identified such as- reusability, interaction complexity, understandability, testability and stability.

Maintenance activities are implementing four areas of focus:

- Corrective maintenance: In this, modification of software is performed after finding the faults and Problems. Maintenance perform changes to correct these fault in the software
- Adaptive maintenance: Correction is performed of the software after the delivery to keep the software remains usable changed or changing environment.
- Perfective maintenance: Correction is performed to revise performance by adding, modify and delete functions, improve ease, rewriting documentation and improve efficiencyof use noted. Otherwise, changes are coming difficult and their cost will be more expensive.
- Preventive maintenance: Correction is performed of the software after the delivery such that the hidden faults get identified and corrected before they become big fault.

Need of Effort Estimation for Maintenance: It is very difficult to preserve, modify and comprehend the software. There is no fixed formula and criteria to evaluate

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maintainability. In this survey, we did comparative study to achieve maintainability by using soft computing techniques. It is very typical to estimate software quality attribute directly. Maintainability affected by different factors, there is no direct method to measure maintenance quality factor.

Evolution of Soft Computing in Effort Estimation for Maintenance: There is some existing research work by the using soft computing techniques to estimate the software quality in procedural and object paradigm. [15] khoshoftaar used neural network with backpropagation algorithm using to organize modules is suffering from fault or not. [16]. In this work, to clustering the number of fault a fuzzy subtractive clustering is used. The inputs were average cyclomatic complexity, comment ratio, average life spanand average live variable. The output of this model is corrective maintenance time.

Gyimothy *et al.* [18] factual approved Kemerer and chidamber gives metrics for fault prediction in open source software. They uses machine learning method and regression method for estimate fault proneness.General Regression Neural network for forecasting software fault used by Quah and thwin.

Make a comparison of various soft computing techniques and make a hybrid ANFIS approach [4]. They use this hybrid approach by taking advantages from ANNs and FIS. And compare three soft computing techniques. The conclusion is find that ANFIS gives more effective maintenance prediction.

Selective Techniques: There are various soft computing techniques are using in existing work on achieving maintainability. Some of the techniques are describing below.

Feedforward Back Propagation Neural Network: The Feedforward Backpropagation [19] is the first simplest model of the artificial neural network. This neural network provides various types of training algorithms. 15 algorithms are used in the MATLAB toolbox. To achieve maintainability the output is taken as maintenance effort. Input can be taken on the input layer relate with quality characteristics as illustrated in Figure 1.

FALCON (Fuzzy Adaptive Training Control Network): FALCON [19] is a 5 layers architecture. One input layer, one output layer and three hidden layers. The last two distinguish node are for output. One is for output of FALCON and another one is for Patterns. The first hidden layer is used for mapping of the input variables to each membership functions. The second hidden layer is responsible for the antecedents of the rules that are feed in the third hidden layer as illustrated in Figure 2. FALCON uses an unsupervised learning to grow the membership functions and rule base. It uses it as the hybrid learning algorithm and also uses a learning algorithm states on the gradient descent to adjust the final parameters of membership function to create the desired output.

ANFIS (Adaptive Neuro Fuzzy Inference System): The ANFIS [20] has five layers asshown in Figure 3. It implements a fuzzy inference system of Takagi Sugeno. The first hidden layer is used for representthe input variable with each membership functions. The T-norm is applied to all rules in the second hidden layer. The rules strengths are normalized in third hidden layer followed by the fourth hidden layer all rules are determined. The output layer gives the global output of all the signals as summation. ANFIS uses the least mean square method to determine quality parameters and backpropagation learning to find out the parameters of input membership functions. The iterative learning algorithm has two parts in each steps. In the first part, the parameters are findwith the use of iterative minimum squared method algorithm and the input patters are propagated. The parameters of all assertion are fixed.

FIS (Fuzzy Inference System): Fuzzy inference system [21] is used for mapping input to the output by using fuzzy logic. It involves fuzzy logic operators, membership function and if and else rules. It is used in the field such as data classification, expert systems and decision analysis. The fuzzy inference system is also known as fuzzy model, fuzzy rule based system, fuzzy associative memory, fuzzy expert system and simply fuzzy system. A block diagram of FIS is shown as in Figure 4. The rules for FIS are generated by expert knowledge. We used these rules based on cluster estimation in the maintenance effort estimation. So subtractive clustering is used in the data set. The main advantage for using clustering is to generate the resultant rules. In MATLAB toolbox the FIS was generated in fuzzy logic by genfis.

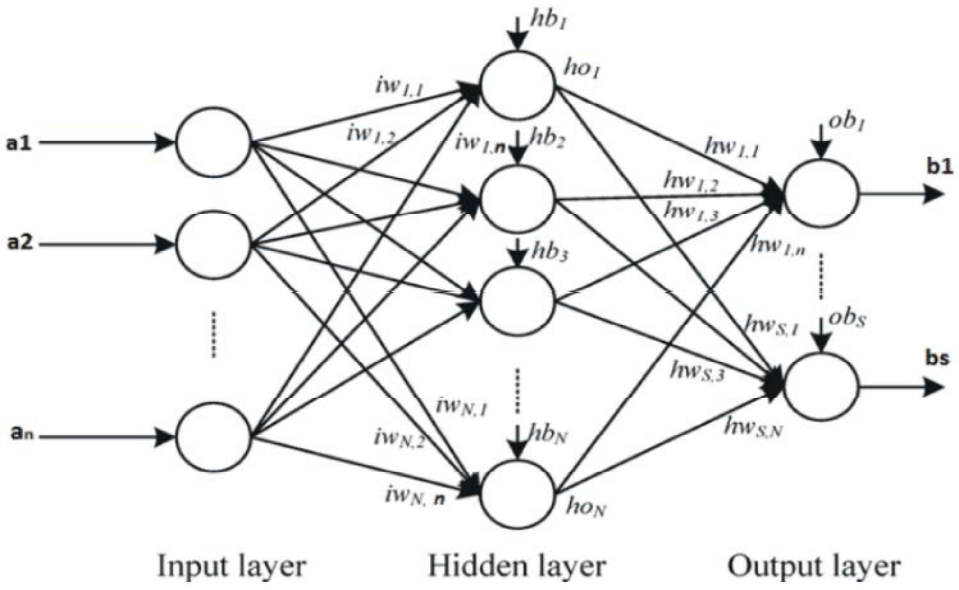

Fig. 1: Feedforward Back Propogation Neural Network

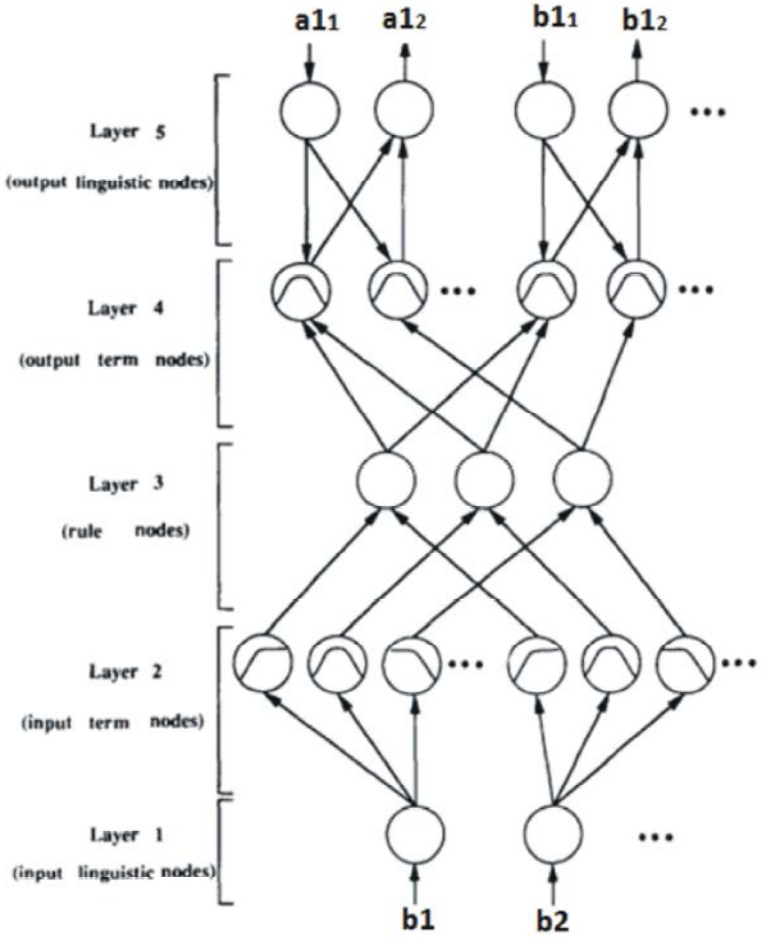

Fig. 2: Fuzzy Adaptive Training Control Network

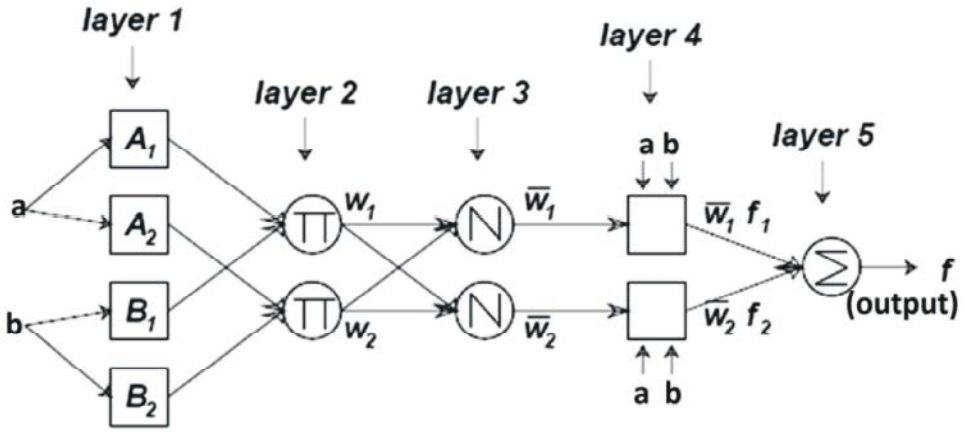

Fig. 3: Adaptive Neuro Fuzzy Inference System

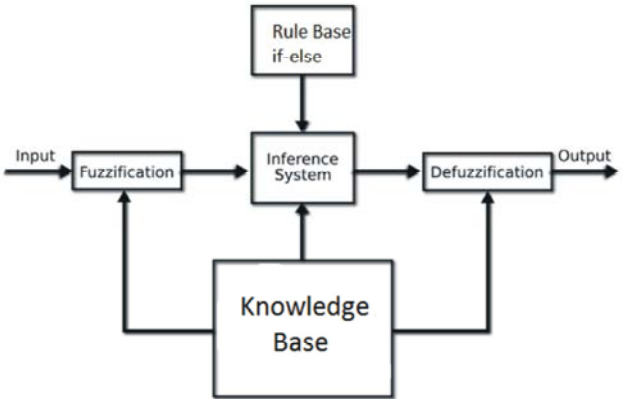

Fig. 4: Fuzzy Inference System

Table 1: Performance Parameters

Parameters	Formula
MARE (Mean Absolute Relative Error)	$MARE = \left(\sum_{i=1}^{k} \left\| \frac{desired - actual}{actual} \right\| \right) \div k$
MRE (Mean Relative Error)	$MRE = \left(\sum_{i=1}^{k} \frac{desired - actual}{k} \right) \div k$
RMSE (Root Mean Square Error)	$\mathrm{RMSE} = \sqrt{\frac{1}{k} \sum_{i=1}^{k} (y_i - y_i')^2}$
MAE (Mean Absolute Error)	$\mathrm{MAE} = \frac{1}{k} \sum_{i=1}^{k} \lvert y_i - y_i' \rvert$

Machine Learning: Machine learning is a set of methods or data that automatically detects pattern of rules and helps in estimation. It performs the job integrated with artificial intelligence. Tasks are pattern recognition, planning, prediction, robot control, diagnosis etc. it is used when human expertise not there or unable to expertise. So that, in the prediction of software maintenance human expertise is unable to achieve the maintainability. That's why it is very useful in the software maintainability effort estimation.

Parameters: To forecast the accuracy of soft computing algorithms we compare the following parameters to find effective results [22] [23].

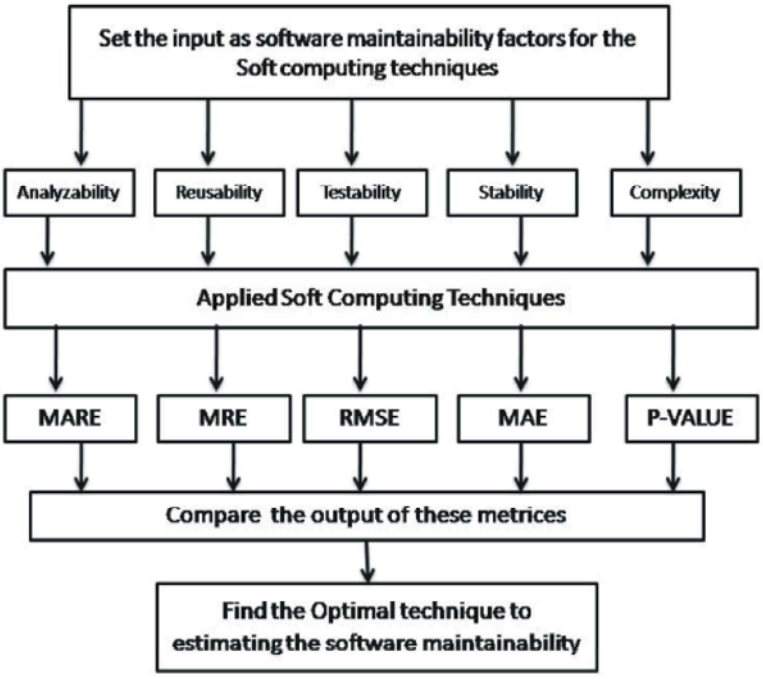

Fig. 5: Structure of the comparative study

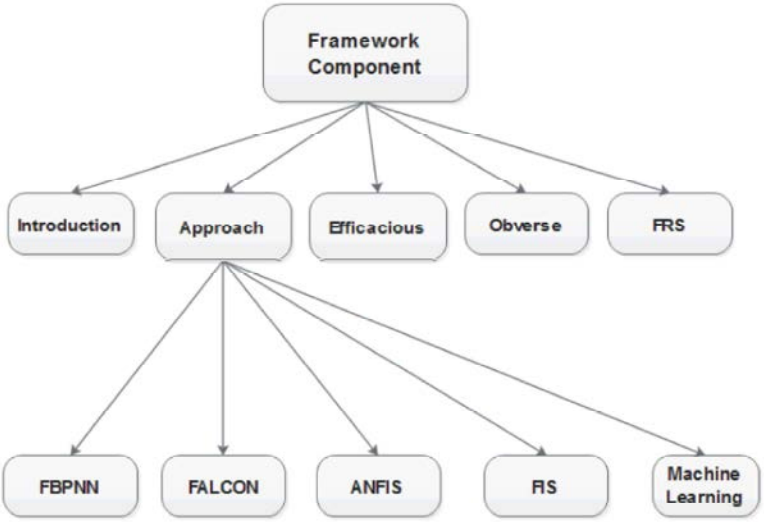

Fig. 6: Framework of the proposal

Comparative Study of Selected Approaches: In this work we evaluate the different selective soft computing approaches for estimating the software maintenance effort; a structure is shown in Figure 5. We use different parameters such as reusability, analyzability, testability, stability, complexity as an input given to the various soft computing techniques. These parameters are passing as an input to selective techniques such as ANFIS, FIS, Machine Learning, FALCON, Feedforward Backpropagation Neural Network. On the basis of MARE, MRE, RMSE, MAE, P-value, R-value we compare the these metrics and find which soft computing approaches is more suitable. In this survey we find that ANFIS model is best as followed by MARE and MRE. MARE of FIS is 30.8% and while MARE of ANFIS is 24.2% and 36.8% MARE value of Backpropagation Artificial Neural Network. So mean absolute relative error of ANFIS model is very least and MRE is very least as in comparison [4].

In this work we contrast Backpropagation, NFTOOL, NTSTOOL and Adaptive Neuro Fuzzy Inference System for estimating the software maintenance. Compare MSE of these approaches and obtained MRE for ANFIS is 23.7, MRE for NFTOOL is 33.53and for the NSTOOL is 349.53. So that Mean Relative Error for ANFIS is very least. Hence we find that ANFIS model gives the effective results and suitable in software maintenance prediction purpose [9].

In this literature survey we studied various soft computing techniques used in object oriented based software. ANFIS is implemented to find the outcome by using the QUES data for estimation effort. In this survey various approaches are used but in comparatively ANFIS gives the effective outcomes for maintenance prediction [14].

So that, in this literature survey we observe that Adaptive Neuro Fuzzy Inference System gives fruitful results as compare to other approaches. FIS model also gives good result as compare other soft computing models except ANFIS model.

Proposed Structure for Categorizing of Proposals: A framework of the proposal is shown in Figure 6.

- Introduction– In the introduction, the problem is introduced and discusse show to solve them. It basically provides the objective of the method used.
- Approach– Various approaches will discuss and critically analyses the proposed methods in area of effort estimation for maintainability. We will focus, here, only soft computing techniques. A short description of the methods will also be provided.
- Efficacious– This section will describe the advantages of proposed methods, their upsides, contribution to the field and essential factors. Value creation by the method will also be discussed with a discussion on their efficiency and accuracy to solve the given problem.
- Obverse– In this section, we will examine those essential points that are not given their due consideration. These points may cover side-effects, disadvantages or gap in research.
- Future Research Scope– Future research scope of the proposed methods will be discussed in this section. Limitations and/or challenges to improve upon set the direction for future research.

Structural study for Maintainability Prediction:

Soft Computing Approaches for Prediction of Software Maintenance Effort [4]

Introduction	In this paper the evaluation and comparison of different soft computing approaches– Artificial Neural Networks, FISand ANFIS for prediction of Software Maintenance Effort.
Approach	The predictive accuracy of Soft Computing techniques was compared using performance measures mean absolute relative error (MARE), Mean Relative Error (MRE), R-value and P-values. The outcomes shows that MARE of FIS model is 30.8%, while that of ANFIS model is 24.2% and Feed forward Neural Network model is 36.8%. It is concluded that ANFIS gives effective outcomes.
Efficacious	The main advantage of this work is that, soft computing techniques can be used for constructing accurate models for estimation of software maintenance and Adaptive Neuro Fuzzy Inference System technique gives the most effective results.
Obverse	In this approach Mean Absolute Error could be compare for good result.
Future Research Scope	In future, the ANFIS technique will be more applicable in observing any software.

Software Maintainability Prediction Using Soft Computing Techniques [5]

Introduction	In this research paper a fuzzy logic approach is proposed for predicting maintainability of CBS (Component Based System). A framework for CBS is proposed for maintenance which gives a coherent process of solving maintenance problem. By using soft computing techniques, an approach is composed that automatically predict software maintainability levels i.e. very good, good, medium, poor and very Poor.
Approach	It has to proposed a fuzzy logic approach for predicting maintainability of CBS(Component Based System). It is very typical to estimate software maintainability directly. Maintainability is affected by many different factors such as understandability, stability, reusability, analyzability, modularity etc.
Efficacious	The soft computing approach is beneficial to estimate software maintainability levels i.e. very good, good, medium, poor and very poor.
Obverse	This approach is predicting maintainability levels only but we cannot for mulate maintainability directly.
Future Research Scope	It can be a powerful tool for important problems in software engineering. It can be further extends as software metric model, effort estimation, cost estimation model, quality prediction and software reliability.

A Fuzzy Approach for Evaluation of Maintainability of Object Oriented Software System [6]

Introduction	This paper proposes a fuzzy model for effort estimation of software maintainability. The inputs for the proposed model are complexity, class, coupling, inheritance and number of children on which maintainability depends and gives the output that helps in achieving software maintainability.
Approach	The model takes object-oriented software and finds its maintainability. Rule base were generated by expert's knowledge, with 243 rules for evaluating object-oriented software system. The results are validated by the AHP (Analytic Hierarchy Process) technique.
Efficacious	This model will help maintainability practitioners, software developers and researchers to select the best maintainable object-oriented software system.
Obverse	RFC (Response For Class), WMC(Weighted Method Complexity), LCOM(Lack of Cohesion of Methods), NOM (Number of Methods), DAC (Data Abstraction Coupling) could also be use as input for achieving good maintainability.
Future Research Scope	In future, the ANFIS technique will be more suitable in observing of any other object-oriented models and software.

Software Maintainability Prediction Using Neural Networks [7]

Introduction	The aim of this paper is to find how we get software maintainability in Object oriented system using train neural network.Li-Henry data is used thefor maintainability estimation. It can be determined as output of the trained neural network.
Approach	There are various training algorithms (trainscg, trainlm, traingdm, trainbfg, traincgp, trainoss, trainr, trainrp) are used. After training the neural network, a set of input values are provided as, LCOM(Lack of Cohesion of Methods), DIT(Depth in the Inheritance Tree), MPC(Message Passing Coupling), NOM(Number of Methods), RFC(Response For Class), DAC (Data Abstraction Coupling), NOC(Number of Children), WMC(Weighted Method Complexity).
Efficacious	This work is used for effort estimation of software maintainability in the industries for manufacturing software application for keeping in the view of software maintenance. It can be used cost and risk analysis as required in effort estimation.
Obverse	It is very typical to design own training algorithm.
Future Research Scope	In this research paper neural networks algorithms is used in future work, we can plan to design our own training algorithm for better outcomes in effort estimation. These algorithms can be based on support vector based algorithms, Fuzzy Logic Algorithms and Artificial Intelligence based algorithms.

Fuzzy Layered Approach for Maintainability Evaluation of Object Oriented Software System [8]

Introduction	The aim of this paper is to estimate the software maintainability by using fuzzy layered approach using AHP(Analytic Hierarchy Process). The layered approach allocates system figures from bottom to top. With the relationship of 1st and 2nd layer maintainability estimation is achieved. For making decisions Analytic Hierarchy Process is used.
Approach	In this paper layered approach is used to achieve maintainability for object oriented software systems. These approaches use three layers, 1st layer use to select the criteria that is maintainability. 2nd layer is used for sub criteria such as stability, changeability, testability and analyzability. The 3rd layer used four sub- criteria - coupling between objects, weighted methods per class, number of children, depth of inheritance tree, and responsefor a class.
Efficacious	Accuracy has been achieved by applying this model and It also effectiveness for fuzzy layered approach in estimation of maintainability of object oriented software. It is also useful in assessment of maintainability framework.
Obverse	This approach is effective but typical.
Future Research Scope	The future work would deal with the determination of the exact value of maintainability and realization of the full potential and possible disadvantages of fuzzy layered technique.

The Comparative Study of Forecasting Analysis Based on Backpropogation (NFTOOL and NTSTOOL) and Adaptive nuero fuzzy interference system ANFIS [9]

Introduction	In this paper ANFIS accurately predict maintainability as compared to other models. There are three soft computing techniques are used. The outcome of these techniques is assess and compared. It is concluded that ANFIS gives the more effective result to software maintainability effort estimation.
Approach	In the work we have compared three different techniques such as Backpropagation (NTSTOOL and NFTOOL) and ANFIS in prediction of software maintainability. Comparing mean square error(MSE), the MSE of ANFIS is 23.7, NFTOOL is 33.53 and MSE of NSTOOL is 349.53. This concludes that ANFIS gives better result for effort estimation.
Efficacious	This research has been done for a small system and therefore the results needs to be generalized by conducting similar analysis on data of other large real time systems.
Obverse	In this approach we could also compare MARE (mean absolute relative error) and MRE (mean relative error) for effective results.
Future Research Scope	In future we are planning to take other paradigms apart from those taken in this study and perform validation on it.

Maintainability Prediction - An Artificial Neural Network Based Approach [10]	
Introduction	In this research paper software maintainability prediction is done by using artificial neural network based approach and the obtained result shows that network is able to predict the maintainability of software with an acceptable accuracy. Also discuss backpropagation neural network based approach for maintainability effort estimation.
Approach	An ANN (Artificial Neural Network) approach is used to predict the maintainability of software. Network is trained on training data by considering different number of hidden neurons for two training functions namely trainlm and trainbr to get the best results. Neurons in the hidden layer are increasing in each iteration and calculate Root Mean Square Error (RMSE) for trainlm and trainbr functions.
Efficacious	It is also possible to train the network by using different combinations of other training functions, transfer functions and number of hidden layers.
Obverse	To achieve good result MARE (mean absolute relative error) could be examine.
Future Research Scope	This approach is the acceptablefor proposed model in real-life projects.

Prediction of Software Maintainability using Neural Networks [11]	
Introduction	In this paper, the three models GRNN (General Regression Neural Network), GMDH (Group Method of Data Handling) and PNN (Probabilistic Neural Network) of neural network is used to achieve maintainability. Each model is compared on the basis of measures: MMRE, MRE, Pred (0.25) and pred (0.25). In this paper, open source software is composed to calculate the CHANGE. It defines the number of line is added, modified or deleted from the software. Hence it is conclude that the GRNN model is the best neural model in maintainability effort estimation.
Approach	The three models are designed to achieve maintainability by using neural network models. The model is group by GMDH, PNN and GRNN and compare by four measures: Pred (0.25), MMRE, MRE and pred (0.25). So the conclusion is that GRNN gives the efficient outcome in maintainability effort estimation.
Efficacious	GRNN is the best suited model for software maintenance effort estimation.
Obverse	The GRNN (General Regression Neural Network) model could be compared with the ANFIS (Adaptive neuro Fuzzy Inference system) to find the best approach for effort estimation.
Future Research Scope	In future, GRNN can be use with other data mining models that would gives more accurate in software maintainability effort estimation.

Software Maintainability Assessment Using Soft Computing Techniques: Review [12]	
Introduction	The aim of this research paper is to survey that the soft computing techniques are very much applicable to predict software maintainability and gives satisfactory result. Author gave the overview of various quality models emphasizing on maintainability and provide the analysis of maintainability of various quality models.
Approach	In this paper software maintainability assessment discussed using soft computing techniques namely fuzzy, neural network and neuro-fuzzy.
Efficacious	In this paper, author not only discusses the problem associated with maintainability but also gives the way to solve them.
Obverse	The strategies are not giving the effective solution to the problems.
Future Research Scope	Author considered different papers that give various techniques. These techniques are very important in the area of research, science and mathematics.

Measuring of Software Maintainability Using Adaptive Fuzzy Neural Network [13]	
Introduction	In this paper ANFIS is used to achieve maintainability by set optimize parameters delayed with fixed parameters and find the RMSE is 0.34331.
Approach	ANFIS is used to provide a method for evaluating the capability of software maintenance. There are 5 inputs ability to read, modularization, validation and testing and return on investment, The size of the project team and output is maintainability.
Efficacious	Accuracy and performance of the proposed method is suitable for evaluating the capability of software maintenance.
Obverse	Input could be extending to effective outcome in effort estimation.
Future Research Scope	The future work it can be gives exact value or formula of software maintainability prediction.

Maintainability Prediction of Object Oriented Software by using AdaptiveNetwork based Fuzzy System Technique [14]	
Introduction	The aim of this paper is to implementing and enhancing the existing technique of maintainability effort by reducing the ten OO metrics to five and hence getting the results. In this research paper achieving maintainability by using five OO metrics rather than ten metrics. It is clear that using ten OO metrics increasing the overhead of the working mechanism so if we can reduce it to some extent it will be helpful for implementation. 21.711% accuracy is achieved with the reduced number of metrics.
Approach	In this work the various soft computing techniques to implement software maintainability and implemented the result by Adaptive Neuro Fuzzy technique which uses QUES training data for predicting the value of change variable.
Efficacious	This technique was able to predict the maintainability in terms of change variable by using five metrics in place of ten metrics which reduce the overhead of calculating the same output with ten OO metrics.
Obverse	Other soft computing techniques can also be compare to find good result.
Future Research Scope	This approach is useful in software engineering domain that shows OO behavior due to cumulative effects of other object oriented metrics.

CONCLUSION

The purpose of this literaturere view is to view and compare the various approaches of soft computing techniques to achieve software maintainability. All the narration on researcher views has changed and still changing.There is no exact technique to achieve maintainability. In fact it is very typical to find the accurate maintainability projection. Prediction is done on the basis of some factors as analyzability, changeability, stability and testability. Many researchers are working to find the efficient technique and compare the relative errors of different soft computing techniques. There are different papers which are all about to maintainability. These papers discuss a clear understanding of various models of maintainability estimation. These papers not only discuss the various problems affiliated with maintainability but also give effective strategies to solve these problems. Many researchers used various sub factors of maintainability in these papers to forecasting the maintainability using soft computing techniques.

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