Int. J. Advance Soft Compu. Appl, Vol.9, No. 3, Nov 2017
ISSN 2074-8523

Neuro-Fuzzy Approach for Software Release Time Optimization

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Abstract

Software reliability is a measure of quality of the software. Cost is another very important feature that is to be kept in mind by developers while releasing any software. To deliver a project successfully, it is important to release it on time with minimum cost and maximum reliability. Software release time determination problem deals in optimization of release time of software under several constraints. Optimization methods like crisp optimization, fuzzy logic optimization, and neural network optimization have been discussed in literature. In this paper, neuro fuzzy optimization of software release time determination is proposed with constraints like maximum reliability and minimum cost. Neuro fuzzy optimization method combines the best features of fuzzy logic and neural network. The proposed model is tested on a real time data set and results are appreciated.

Keywords*: Software release time, reliability, optimization, fuzzy logic, neuro fuzzy optimization*

1 Introduction

Software systems have become an integral part of our daily life. Software is embedded in almost all the machinery these days, ranging from home appliances to missile system. Software industry is the most rapidly growing industry. The success of this rapid growth is solely dependent on the software development plan. Complex software systems are coming up every day. To develop software successfully, the main aim of the software team is on the timely release of the software with minimum cost with best quality. The focus of the organization is to

optimize the time with respect to cost and reliability. Many researchers in the literature have proposed optimization methods for optimization of the software release time but none of the models can be applied to all. Various optimization methods discussed in literature like crisp optimization, fuzzy logic optimization and neural network optimization.

Crisp optimization of software release time problem was first discussed by Okumoto and Goel [13] with objective function as minimization of cost and reliability as a constraint. Kapur et al [8] discussed bi-criteria software release time problem with minimization of cost and maximization of reliability. Later, Release time policy with introduction of penalty cost in the cost function was discussed by Huang and Lyu [6]. The inputs cannot be crisp always and may depend on several other factors like size of team, experience etc. These inputs can be considered as fuzzy and can be described in linguistic terms and hence is considered as more flexible. Many researchers have discussed about fuzzy optimization problem of software release time. Jha et al. [7], formulated a release time policy of discrete SRGM under fuzzy environment. Dohi et al. [4] discussed optimization of software release time using neural network. Gautam et al. [14] also discussed about optimization of release time with minimization of cost and maximization of reliability as constraints using neural network optimization method. Neuro-fuzzy research area is relatively new area of optimization which combines fuzzy logic and neural network to achieve higher accuracy. In neuro-fuzzy systems the output of fuzzy system is incorporated as input of neural network [3].

The objective of the paper is to propose a new model of software release time optimization with objectives as cost minimization and reliability maximization using neuro-fuzzy method. The flow of the paper is as follows - In Section 2, existing optimization methods of software release time are discussed, proposed model is discussed in section 3. A numerical example and results of the proposed model is discussed in section 4. Conclusions are made in Section 5.

2 Existing Software Release Time Optimization

Neural network research started in 1940s, it has the ability to learn from the environment, to self organize its structure and adapt to it in an interactive manner [2]. Fuzzy logic research started in 1960s and was first proposed by Zadeh [1]. Fuzzy rule based models are easy to comprehend as they use linguistic terms to describe any uncertainty involved with the variable and have if-then rules.

M1: FUZZY OPTIMIZATION OF RELEASE TIME PROBLEM

Fuzzy optimization of release time problem was discussed by Sharma et al. [16]. In Fuzzy Optimization of software release time problem, Zimmermann's approach

is used. The first step is to restate the problem with fuzzifier in objective function included as a restriction level constraint. In step 2, the problem is restated by including the objective function as one of the constraints. Then the membership function μi(T); i= 1, 2 is defined for each of the fuzzy inequality in the stated problem. Next Bellman and Zadeh's principle is used to identify the fuzzy decision to solve the fuzzy system of inequality corresponding to the problem. The resulting crisp optimization problem is solved using crisp mathematical programming approach.

M2: NEURAL NETWORK OPTIMIZATION OF RELEASE TIME PROBLEM

Software release time optimization problems are also solved by using artificial neural network method. Artificial neural network corresponds to the biological neurons. Artificial neural network [12] is many inputs and one output method. Neurons take the inputs, process them and give the output. In neural network, apart from taking input and output we have one more layer in between called the Hidden layer. Artificial neural network is formed by group of artificial neurons that are interconnected with each other. Neural network optimization of release time problem was discussed by Gautam et al. [14].

Neural network requires past data for processing the knowledge. The network architecture is used to find the optimal release time of the problem by considering minimization of cost and maximization of reliability. The activation functions of the hidden layer and output layer are defined. Weights are attached with the input layers and hidden layer. Selecting the data set and using above model we train our neural network and find out the time of release of the software.

Fuzzy logic is highly recommended in modeling of software release time problems to deal with the imprecision or vagueness of the input values. Unlike neural networks, fuzzy logic does not come with a learning algorithm. For learning and identification of fuzzy models they need to adopt techniques from other areas. Since neural networks can learn, so it is natural to merge two techniques into one. When the concept of fuzzy logic is incorporated into neural network, the result is neuro fuzzy system that has the advantages of both [3].

3 Proposed Neuro Fuzzy Model for Software Release Time Problem

In this paper, we have proposed a neuro fuzzy model for software release time problem. A neuro fuzzy model is developed which uses hybrid learning algorithm to tune the parameters of fuzzy inference system. The neuro fuzzy model uses neural network learning algorithms and fuzzy reasoning to map an input space to an output space. With the ability to combine the verbal power of a fuzzy system with the numeric power of a neural system adaptive network, this model has been shown to be powerful in modeling optimization problem.

Neuro-fuzzy optimization combines the human-like reasoning style of fuzzy systems with the learning and the connectionist structure of neural networks. It incorporates the human-like reasoning style of fuzzy systems using fuzzy sets and a linguistic model. The main strength of neuro-fuzzy systems is that they are universal approximators with the ability to solicit interpretable IF-THEN rules.
A neuro-fuzzy system can be viewed as a 5-layer feedforward neural network. The first layer represents input variables, the middle (hidden) layers represent fuzzy rules and the fifth layer represents output variables. Fuzzy sets are encoded as (fuzzy) connection weights.

The neuro fuzzy model to find the optimal release time with minimum cost and maximum reliability is proposed as follows:

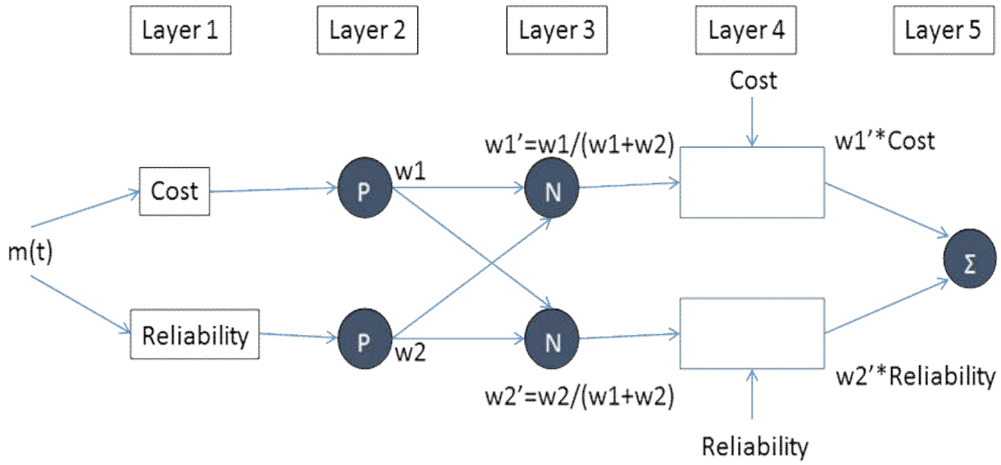

Fig. 1: Proposed Neuro Fuzzy Model for optimal release

The model is with one input and two rules cost and reliability and one output time. The different layers of the model are described below:

Layer 1: In this layer, the membership function of two inputs cost and reliability are taken. We have considered three different membership functions viz. Triangular, Trapezoidal and Gaussian membership functions for both cost and reliability as three cases. The Triangular membership function is specified by three parameters (a, b, c) as follows:

$$\mu_A(x;a,b,c) = \begin{cases} 0 & ; x \le a \\ \dfrac{x-a}{b-a} & ; a \le x \le b \\ \dfrac{c-x}{c-b} & ; b \le x \le c \\ 0 & ; c \le x \end{cases} \qquad (1)$$

The parameters (a ,b, c) determine the x coordinates of the Triangular membership function.

The Trapezoidal membership function is specified by four parameters (a, b, c, d) as follows

$$\mu_A(x;a,b,c,d)=\begin{Bmatrix}0 & ;x\le a\\ \frac{x-a}{b-a} & ;a\le x\le b\\ 1 & ;b\le x\le c\\ \frac{d-x}{d-c} & ;c\le x\le d\\ 0 & ;d\le x\end{Bmatrix} \quad (2)$$

The parameters (a, b, c, d) such that a≤ b≤ c≤ d, determine the x coordinates of the four corners of the Trapezoidal membership function.
A Gaussian membership function is specified by two parameters (c, σ)

$$\mu_A(x;c,\sigma)=e^{-\frac{1}{2}(\frac{x-c}{\sigma})^2} \quad (3)$$

where c and σ represents centre and width of membership function respectively.
The three parameters in this study are C(T), C(T)*, C(T)0 which are defined as cost of testing, total budget available and tolerance level of cost respectively and the membership function is defined accordingly.
Similarly for reliability membership function the three parameters are R(T), R(T)*,R(T)0 which are defined as reliability during testing, reliability value set by the management and tolerance level of reliability respectively.

Layer 2: In layer 2, we have the fixed node as P, the output of the nodes are given as:

$$w1 = P_C = \min(\mu_C(x), \mu_R(x)), \quad (4)$$

$$w2 = P_R = \max(\mu_C(x), \mu_R(x)) \quad (5)$$

Since cost needs to be minimized that's why we have used min function with cost and reliability is to be maximized, so we have used max function with it.

Layer 3: Calculate the activation of various rules or nodes for all the activation of strength rules of the intensity ratio or in other words normalize the strength of each node.
The node function for node I is given as:
Wi′=Wi/(W1+W2) (6)

Layer 4: Calculate the weighted output of various rules. The node function for any node i is given as Wi′*fi.

Layer 5: This is the network's output layer, it contains only one node and calculate the output signal of the entire system, the function node:

$Mi=\Sigma (Wi'* fi)$

Through the steps above neuro fuzzy network can effectively calculate the optimal time of software release.

4 Numerical Example

To illustrate the practical application of the neuro fuzzy model in software release time determination problem, the real-time data set from Brooks and Motley is used. The input parameters are cost and reliability and the output is time. The objective function is to release the software with minimum cost and maximum reliability. The values of cost and reliability are predicted from the mean value function of failure phenomenon given by Sharma, Kumar, Kapur [15]. The cost function and reliability is expressed as function of m(t) and are expressed as

$$Co(T) = Co_1 T + Co_2 m(T) + Co_3 (m(T + T_s) - m(T))$$

$$R((T+Ts)|T)= e(-m(T+Ts)-m(T)) \quad (7)$$

We considered the SRGM from Sharma et al [15]. It is assumed that parameters a and b of SRGM have already been estimated from the testing data set by collected by Brooks and Motley. The total budget available to the management is CoT0 = 24000, and reliability requirement by the release time is R0 =0.95 with tolerance levels on cost and reliability CoT*=25500 and R*=0.75.

Using above values of various parameters and constants, solution of the software release time problem is obtained with the neuro fuzzy optimization method discussed above and considering different membership functions one at a time. The results are calculated as follows:

4.1 TRIANGULAR MEMBERSHIP FUNCTION

The parameters (a, b, c) of triangular membership function are taken as follows:

Parameters	Cost	Reliability
a	24000	0.75
b	25000	0.80
c	25500	0.95

Table 1: Neuro Fuzzy optimization with Triangular MF

Time	LAYER 1		LAYER2		LAYER 3		LAYER4		LAYER5
5	1	0	0	1	0	1	0	3.0924E-118	3.0924E-118
10	1	0	0	1	0	1	0	5.5386E-117	5.5386E-117
15	1	0	0	1	0	1	0	2.4214E-100	2.4214E-100
20	1	0	0	1	0	1	0	4.46185E-80	4.46185E-80
25	1	0	0	1	0	1	0	3.33311E-61	3.33311E-61
30	1	0	0	1	0	1	0	1.78378E-45	1.78378E-45
35	1	0	0	1	0	1	0	3.83858E-33	3.83858E-33
40	1	0	0	1	0	1	0	7.75293E-24	7.75293E-24
45	1	0	0	1	0	1	0	5.3328E-17	5.3328E-17
50	0.905	0	0	0.905	0	1	0	4.51773E-12	4.51773E-12
55	0.785	0	0	0.785	0	1	0	1.42796E-08	1.42796E-08
60	0.698	0	0	0.698	0	1	0	4.0888E-06	4.0888E-06
65	0.632	0	0	0.632	0	1	0	0.000209066	0.000209066
70	0.582	0	0	0.582	0	1	0	0.003158616	0.003158616
75	0.542	0	0	0.542	0	1	0	0.020326513	0.020326513
80	0.508	0	0	0.508	0	1	0	0.07235098	0.07235098
85	0.479	0	0	0.479	0	1	0	0.171266125	0.171266125
90	0.453	0	0	0.453	0	1	0	0.306633776	0.306633776
95	0.429	0	0	0.429	0	1	0	0.453918294	0.453918294
100	0.406	0	0	0.406	0	1	0	0.590671185	0.590671185
105	0.385	0	0	0.385	0	1	0	0.704543348	0.704543348
110	0.364	0.21	0.21	0.364	0.369	0.63083318	9212.40721	0.499971123	9212.907182
115	0.343	0.54	0.34	0.536	0.39	0.60991462	9746.56653	0.522826015	9747.089355
120	0.322	0.77	0.32	0.765	0.296	0.70366444	7413.27042	0.635470951	7413.905889
125	0.302	0.92	0.3	0.924	0.246	0.75373251	6168.25307	0.704646707	6168.957719
130	0.282	1	0.28	1	0.22	0.78014759	5513.30203	0.746247567	5514.048278
135	0.262	1	0.26	1	0.207	0.7926018	5207.25005	0.769738024	5208.019788
140	0.242	1	0.24	1	0.195	0.80542856	4891.06628	0.790062335	4891.856345
145	0.222	1	0.22	1	0.181	0.81865591	4564.01877	0.808355055	4564.827124
150	0.201	1	0.2	1	0.168	0.83231047	4225.40533	0.825418336	4226.230747

From Table 1 we can see that at time 115 the cost is minimum and reliability is maximum. Thus the optimal time of release using proposed neuro fuzzy method with triangular membership function is 115 weeks.

4.2 TRAPEZOIDAL MEMBERSHIP FUNCTION

The parameters (a, b, c, d) of trapezoidal membership function are taken as follows:

Parameters	Cost	Reliability
a	23000	0.75
b	24000	0.80
c	25000	0.85
d	26000	0.95

Table 2: Neuro Fuzzy optimization with Trapezoidal MF

	LAYER 1		LAYER2		LAYER 3		LAYER4		LAYER5
Time	COST MEMBERSHIP FUNCTION	RELIBILITY MEMBERSHIP FUNCTION	w1=min(mc, mr)	w2=max(mc, mr)	w1'=w1/(w1+w2)	w2'=w2/(w1+w2)	w1'*Cost	w2'*rel	Summation
5	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
35	0.0275527	0	0	0.0275527	0	0	0	0	0
40	0.5343688	0	0	0.5343688	0	0	0	0	0
45	0.8902613	0	0	0.8902613	0	0	0	0	0
50	1	0	0	1	0	0	0	0	0
55	1	0	0	1	0	0	0	0	0
60	1	0	0	1	0	0	0	0	0
65	1	0	0	1	0	0	0	0	0
70	1	0	0	1	0	0	0	0	0
75	1	0	0	1	0	0	0	0	0
80	1	0	0	1	0	0	0	0	0
85	1	0	0	1	0	0	0	0	0
90	1	0	0	1	0	0	0	0	0
95	1	0	0	1	0	0	0	0	0
100	1	0	0	1	0	0	0	0	0
105	1	0	0	1	0	0	0	0	0
110	1	0.851136	0.851136	1	0.4597912	0.3149705	11473.901	0.249632	11474.15
115	1	0.9278818	0.9278818	1	0.481296	0.3249155	12025.53	0.2785214	12025.809
120	0.983527	0.4691195	0.4691195	0.983527	0.3229413	0.2471865	8078.8516	0.2232311	8079.0749
125	0.9530358	0.1512364	0.1512364	0.9530358	0.1369557	0.1256484	3430.3243	0.1174657	3430.4418
130	0.9227131	0	0	0.9227131	0	0	0	0	0
135	0.8925014	0	0	0.8925014	0	0	0	0	0
140	0.8623626	0	0	0.8623626	0	0	0	0	0
145	0.8322716	0	0	0.8322716	0	0	0	0	0
150	0.8022121	0	0	0.8022121	0	0	0	0	0

From Table 2 we can conclude that the optimal time of release using proposed neuro fuzzy method with trapezoidal membership function is 115 weeks.

4.3 GAUSSIAN MEMBERSHIP FUNCTION

The parameters (c, σ) of Gaussian membership function are taken as follows:

Parameters	Cost	Reliability
c	15000	0.80
σ	5000	0.25

Table 3: Neuro Fuzzy optimization with Gaussian MF

	LAYER 1		LAYER2		LAYER 3		LAYER4		LAYER5
Time	COST MEMBERSHIP FUNCTION	RELIBILITY MEMBERSHIP FUNCTION	w1=min(mc, mr)	w2=max(mc, mr)	w1'=w1/(w1+w2)	w2'=w2/(w1+w2)	w1'*Cost	w2'*rel	Summation
5	0.8297583	0.005976	0.005976	0.8297583	0.0071506	0.9928494	77.483994	0.2340603	77.718054
10	0.9425064	0.005976	0.005976	0.9425064	0.0063006	0.9936994	93.488882	0.2342607	93.723143
15	0.9886535	0.005976	0.005976	0.9886535	0.0060083	0.9939917	106.55054	0.2343296	106.78487
20	0.9999152	0.005976	0.005976	0.9999152	0.005941	0.994059	117.65985	0.2343455	117.89419
25	0.9964132	0.005976	0.005976	0.9964132	0.0059618	0.9940382	126.81651	0.2343406	127.05085
30	0.9882737	0.005976	0.005976	0.9882737	0.0060106	0.9939894	134.05955	0.2343291	134.29388
35	0.979837	0.005976	0.005976	0.979837	0.006062	0.993938	139.59359	0.234317	139.82791
40	0.9726223	0.005976	0.005976	0.9726223	0.0061067	0.9938933	143.71773	0.2343064	143.95204
45	0.9669278	0.005976	0.005976	0.9669278	0.0061425	0.9938575	146.74497	0.234298	146.97927
50	0.9625946	0.005976	0.005976	0.9625946	0.0061699	0.9938301	148.95409	0.2342915	149.18838
55	0.9593396	0.005976	0.005976	0.9593396	0.0061907	0.9938093	150.57126	0.2342866	150.80555
60	0.9568873	0.0059763	0.0059763	0.9568873	0.0062068	0.9937932	151.77722	0.2342861	152.01151
65	0.9550112	0.005992	0.005992	0.9550112	0.0062352	0.9937648	153.08203	0.2344427	153.31648
70	0.9535391	0.0062221	0.0062221	0.9535391	0.006483	0.993517	159.65544	0.2367419	159.89219
75	0.9523455	0.0077263	0.0077263	0.9523455	0.0080476	0.9919524	198.67534	0.2503748	198.92571
80	0.9513417	0.0144685	0.0144685	0.9513417	0.0149806	0.9850194	370.58817	0.293884	370.88205
85	0.9504659	0.0423219	0.0423219	0.9504659	0.0426294	0.9573706	1056.4134	0.3810121	1056.7944
90	0.9496754	0.1426613	0.1426613	0.9496754	0.130602	0.869398	3241.5865	0.4816932	3242.0682
95	0.9489412	0.3835902	0.3835902	0.9489412	0.2878658	0.7121342	7155.2826	0.5203517	7155.803
100	0.9482438	0.7043017	0.7043017	0.9482438	0.426192	0.573808	10608.031	0.5015944	10608.533
105	0.9475697	0.9296977	0.9296977	0.9475697	0.4952399	0.5047601	12342.799	0.4838466	12343.283
110	0.9469102	0.9995569	0.9469102	0.9995569	0.4864763	0.5135237	12139.818	0.5101459	12140.328
115	0.9462591	0.9741543	0.9462591	0.9741543	0.4927372	0.5072628	12311.396	0.50721	12311.904
120	0.9456127	0.9184965	0.9184965	0.9456127	0.4927268	0.5072732	12326.286	0.5044219	12326.791
125	0.9449681	0.8645613	0.8645613	0.9449681	0.4777824	0.5222176	11966.999	0.5147474	11967.513
130	0.9443237	0.8219671	0.8219671	0.9443237	0.4653634	0.5346366	11670.052	0.5226347	11670.575
135	0.9436782	0.7910863	0.7910863	0.9436782	0.4560194	0.5439806	11449.507	0.5282434	11450.035
140	0.9430309	0.7696178	0.7696178	0.9430309	0.4493728	0.5506272	11296.172	0.532071	11296.704
145	0.9423812	0.7550267	0.7550267	0.9423812	0.4448116	0.5551884	11194.897	0.5346116	11195.432
150	0.941729	0.745239	0.745239	0.941729	0.4417624	0.5582376	11131.435	0.5362583	11131.972

From Table 3 we can see that at time 105 the cost is minimum and reliability is maximum. Thus the optimal time of release using proposed neuro fuzzy method with Gaussian membership function is 105 weeks. The results of fuzzy optimization and neural network optimization along with neuro fuzzy optimization with three different membership functions discussed above can be summarized as

Table 4: Comparison of different optimization methods

Methods	Time	Reliability	Cost
Fuzzy Optimization (M1)	135	0.953008	25108.08
Neural Network Optimization (M2)	113	0.728639	24959.2
Neuro Fuzzy using Triangular Membership Function	115	0.8572118	24985.73
Neuro Fuzzy using Trapezoidal Membership Function	115	0.857212	24985.73
Neuro Fuzzy using Gaussian Membership Function	105	0.958568	24922.87

Fig 2, Fig 3 and Fig 4 shows the cost function, reliability function and time of different methods of optimization that are discussed in the paper.

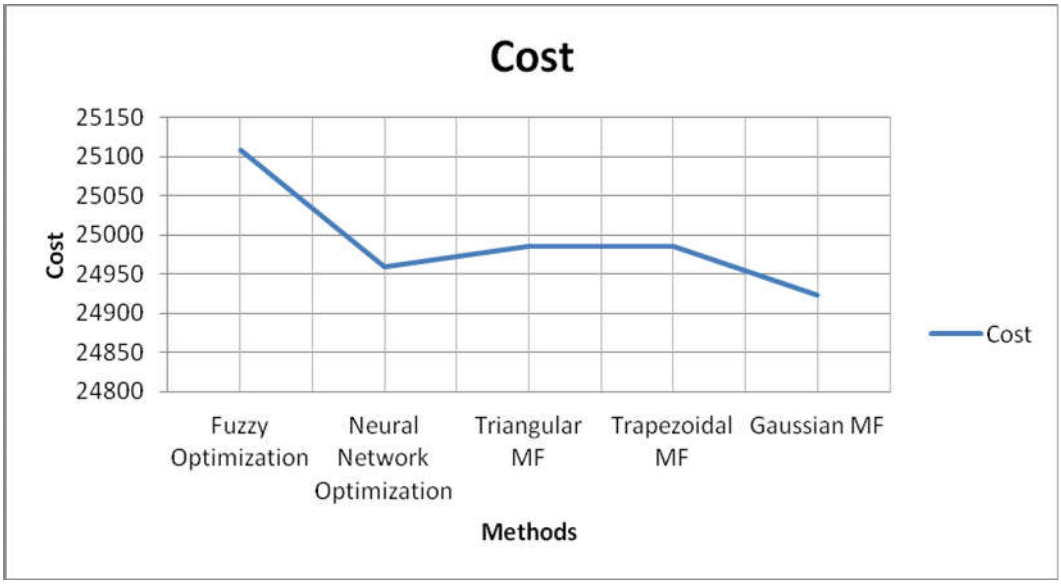

Fig. 2: Cost Function of different optimization methods

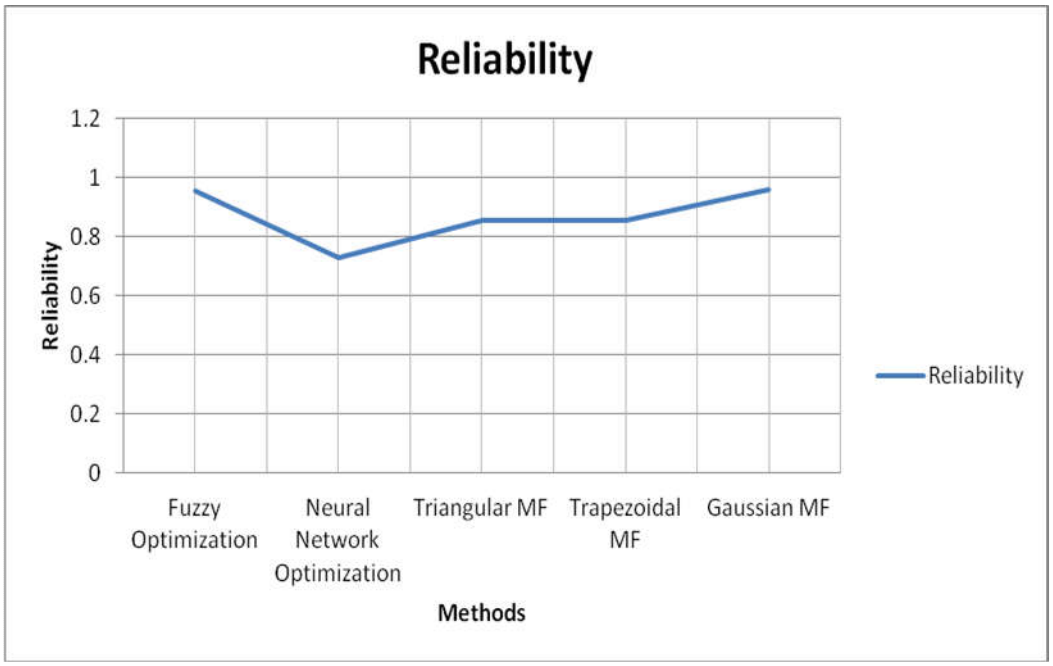

Fig. 3: Reliability Function of different optimization methods

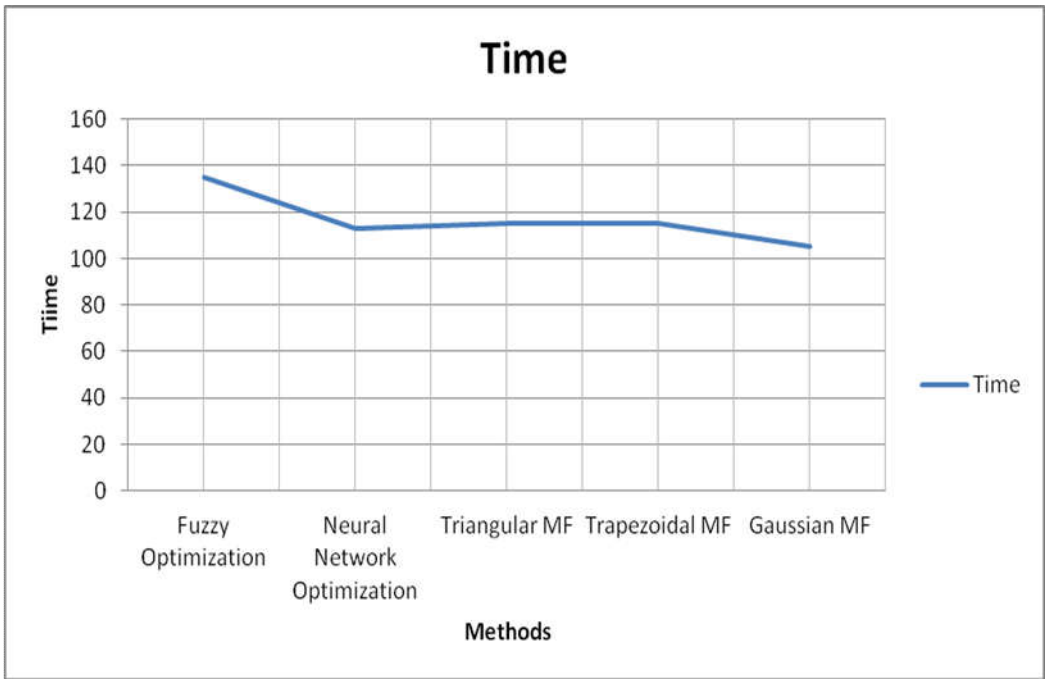

Fig. 4: Time Function of different optimization methods

As per the table above we can see that the software can be released at 105 week with maximum reliability and minimum cost using Gaussian membership function. The figures show that the cost is minimum and reliability is maximum for the Gaussian membership function of neuro fuzzy model.

5 Conclusion

Software release time determination problem is the focus of software developers these days. Main aim of the developer is to release software with minimum cost and maximum reliability. The balance of reliability and cost is very important to release any software. In this paper, we have developed a model using neuro fuzzy model of optimization. An adaptive neuro fuzzy inference system is used for the proposed model. We have used three different membership functions for solving the problem. The model is tested on real time dataset and results are compared with existing methods of optimization and found out that results of Gaussian membership function are the best. In future, we will apply goal programming methods for optimization problem.

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