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Application Of Fuzzy Hybrid Genetic Algorithm For Transmission Line Tower

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***Abstract*—Transmission line tower is optimized using fuzzy hybrid genetic algorithm. Since the convergence is much slower in genetic algorithm, hybrid technique is adopted in this paper to increase the rate of convergence. Analysis is carried out for 25 bar-truss. The fuzzy stress and fuzzy displacement have been used for this application. The aim of this research work is to reduce the weight of the transmission line tower, the constraints of this application are stress and displacement. Constraints are fuzzified and set of rules are constructed for displacement and stress and for their combination. Triangular membership function is used in this problem. If the constraints are violated an effective converging gene is introduced into the chromosome pool to get the best solutions and it is found that the hybrid fuzzy genetic algorithm yielded a very high convergence rate and it is demonstrated in this paper.**

***Keywords*— Genetic Algorithm, fuzzy logic, rule -based systems, 25 bar transmission line tower.**

I. Introduction

Genetic algorithms are used for solving complex real-world problems; however, it is found to be very slow and doing many jobs. The main benefit of this method is excellently insert an expert knowledge gene into the pond of chromosome. In this research work, the authors has concentrated fuzzy rule-based system to regulate genetic based search technology for 25 bar transmission line tower. In this proposed approach, fuzzy knowledge-based system (FKBS) has been introduced. GA's search efficiency has been improved because of the fuzzy rule. Hence, the decision-making performance also improved. In this paper, optimization is carried out for 25 bar transmission line tower, with objective function with fuzzy stress and fuzzy displacement constraint.

Razvan Cazacu and Lucian Grama(2014) has given the optimized solution for the total mass of the structure, The finite element method is used for stress and displacement analysis. H. Kawamura (2002) has developed near-optimal topologies of load-bearing truss structures. This research work depicts the use of a stochastic search procedure. This work is built on genetic algorithms. A.N. Ede etal (2018) developed genetic algorithm in order to improve the plane steel truss structure based on point loading. This is based on the following constraints: stress, displacement and buckling. Chee Kiong Soh and Jiaping Yang (1996) Omer Kelesoglu(2007) investigated fuzzy controlled genetic-based search technique. The more focus has been given on shape optimization.

II. Search Techniques

A. Genetic Algorithms

Principle of natural selection has been implemented in genetic algorithm. Genetic algorithm has emphasized on survival of the fittest. Random selection has been used for initial population for a single bit, where the binary string has been given as the input. Objective function contains strings with the given variables. Family of string has been composed by the random groups. A Family consists of set of parameters that makes a design. Each group is validated with respect to the objective function.

B. Fuzzy Modeling With Rule Based Systems

Fuzzy Logic is the recent advancement and applied in the field of decision making. Giving mathematical description of linguistic uncertainty using fuzzy set is the basic concept of fuzzy logic. IF/THEN statement is based on the condition whether it is true or false. IF the condition is true, the true statement will be executed. If the condition is false, the false statement is executed. By this way, the rule-based system has been implemented. Non- linear relationship can be implemented through IF

THEN models. The following operation can be used for infusion of knowledge: intersection, inference, aggregation etc., Syntax of the IF THEN statement

IF (Antecedent) A
THEN (Consequences) C

Generally, the optimization problem has been designed in such a way that, fuzziness exists during the assessment. Crisp or non-fuzzy number are defining the tolerance. Many approximations are considered in the real-world situation and also in the engineering problem. The following concepts have been given more focus on fuzzy set theory: Fuzziness and imprecision. Consider any given set as Y, Z is denoted as fuzzy set and $\mu_z(y)$ is representing the membership function. The value of the Y lies between 0 and 1. The degree of membership of y in fuzzy set can be explored as the membership function. Hence, the fuzzy set can be represented as given:

$$Z=[y,\mu z(y)]y \varepsilon Y \qquad (1)$$

III. OPTIMIZATION PROBLEM FORMULATION:

When the objective function is crisp, fuzziness is incorporated in the constraints. In this research work, asymmetric problem can be taken and this can be continued for the symmetric problems also.

The following formula is used for optimal weight of the truss.

$$\text{Minimize} \quad f(x) = \sum^{n} \rho x_i l_i \qquad (2) \qquad i=1$$

$$u_j \leq u_a \quad j = 1 \text{ to } ndof \qquad (3)$$

$$\sigma_i \leq \sigma_a \quad i= 1 \text{ to } n \qquad (4)$$

Objective function is denoted by f(x), and it means the total weight of the truss. x_i denotes the cross-sectional area. length of ith member of the truss are represented by l_i . n denotes the number of members. u_j corresponds to the deflection, here j is the iteration in the degree of freedom. u_a corresponds to allowable deflection σ_j is the actual stress in the i^{th} member and σ_a corresponds to allowable stress and The parameter of the number of degrees of freedom is denoted by ndof.

The normalized form of constraints can be written as

$$u_j/u_a - 1 \leq 0 \qquad (5)$$

$$\sigma_j / \sigma_a - 1 \leq 0 \qquad (6)$$

$g_j(x) \leq 0$ is a constraint, the i^{th} constraint is represented by g_i. C represents the violation coefficient and it is computed as follows:

$$\text{If } g_i(x) > 0 \text{ then } c_i = g_i(x); \text{ else } c_i = 0 \text{ and}$$

$$C=\Sigma c_i \qquad (7)$$

The objective function is modified, considering the violation coefficient as

$$\phi(x =f(x) (1 + KC) \qquad (8)$$

where K value is changed with respect to the weight. The modified fitness is defined as

$$F(x) = 1 / \phi(x) \qquad (9)$$

Equations 2 to 9 is used for calculating constraint violation and fitness function

The main requirement of this study is to maximize the fitness.

The weight optimization of truss is obtained by the following steps in genetic algorithm.

i. Initial population can be produced by defining a code using for each design variable followed by mapping it to an integer in a given range are encoded using binary bits.
ii. Compute cross-over and mutation using genetic operators.
iii. Evaluating the fitness function with respect to the objective function. This provides a mechanism for evaluating the performance of each string to optimize objective function.

Rather than pure GA, FKBS is more efficient in searching. It is one of the simulative procedures the way human thinks.

Illustrative Example

Example presented herein to demonstrate the efficiency. A visual FoxPro 6 program has been implemented for 2-D and 3-D truss problems using two-point cross over and mutation operators in GA. The value of probability of crossover is taken as 0.8 and the mutation value as 0.01.

The minimal weight of the trusses and towers can be attained with the following constraints.

1. Stress constraint
2. Displacement constraint
3. Stress and Displacement constraint

A. Implementation of Modified Genetic Algorithm

The fuzzy variable are as follows: Very very low-vvl, Very low-vl, Low-l, Medium-m, High-h, Very high -vh. Fig 3 and 4 show the membership function distribution for stress and displacement function.

B. Rule Base for Various Constraints

The rule-based system is very important in fuzzy logic applications. It is based on the set of rules with respect to the qualitative terms. The output is generated based on the given input. Variation of Magnitude and direction in the design are controlled using this rule. Here 'D' and 'S' are considered as displacement and stress respectively.

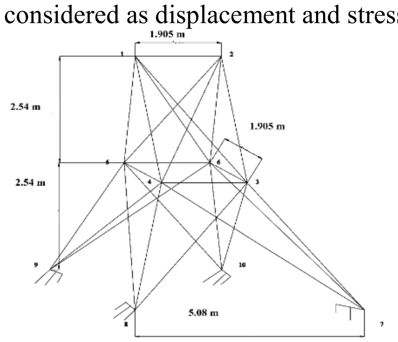

Fig 1. 25 Bar Transmission Tower

C. 25 Bar Transmission Line Truss

The performance of hybrid fuzzy controlled genetic algorithm is tested by doing sizing optimization of 25 bar transmission line tower as shown in Fig.1. The proposed algorithm is implemented to improve the genetic algorithm using fuzzy rule base. The triangular is taken as the constraints for membership functions of stress and displacement in Fg.2 and Fig.3. The main objective of all constraints is to minimize the weight. 275.6 N/mm^2 is taken as an allowable stress and the displacement value as taken as 8.89mm. The above values are only allowable. Table I shows the design data for 25 bar truss used in genetic algorithm. Table II shows the loading applied at the different joints in a 25-bar truss. The 25 elements of the tower are grouped into eight numbers so as to increase the computational efficiency of the genetic algorithm. Element grouping is given in Table III. The optimal value of the areas and weights obtained by the fuzzy controlled various constraints are depicted in Table IV, V and VI. The generation history of the tower is obtained for the different sizes of populations are as follows: 20, 30, 40, 50, 60. Fig 4 and 5 shows the generation history for a generation of 100 for various population of stress and displacement constraint. Fig 6 shows the generation history for population size 30 for various constraint

The design specifications of 25 bar truss are as below.

density = $2.77X10^{-5}$ N/mm^3
Modulus of elasticity = $6.87X10^4$ N/mm^2
Stress = 275.6 N/mm^2
Deflection = 8.89 mm
Probability of Cross over (Pc) = 0.8
Probability of Mutation (Pm) = 0.001
Maximum Generations = 100

The following table I displays the design loads in x,y and z directions respectively. The loads at each joint in all three directions can be seen as below.

TABLE I. DESIGN LOAD FOR 25 BAR TRUSS

Joint Number	F_x (N)	F_y (N)	F_z (N)
1	-4453.74	-44537.4	-44537.4
2	0.0	-44537.4	-44537.4
3	2226.87	0.0	0.0
4	2672.24	0.0	0.0

TABLE II. ELEMENT DISTRIBUTION OF 25 BAR TRUSS

Group Number	Element No
1	1
2	2,3,4,5
3	6,7,8,9
4	10,11
5	12,13
6	14,15,16,17
7	18,19,20,21
8	22,23,24,25

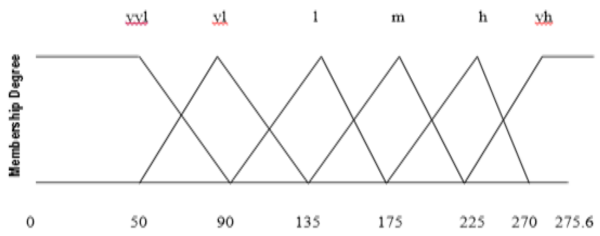

Fig 2. Membership Function for Stress Constraint

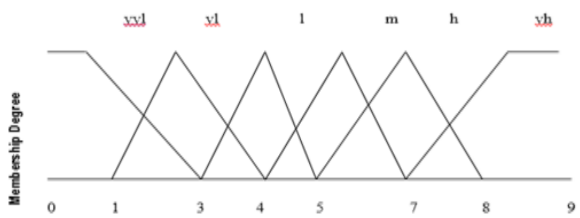

Fig 3. Membership Function for Displacement Constraint

TABLE III. OPTIMAL SIZING VARIABLES FOR 25 BAR TRUSS USING FUZZY CONSTRAINTS (STRESS CONSTRAINT)

Areas in mm^2	Population Size				
	20	***30***	***40***	***50***	***60***
A_1	709.68	709.68	387.1	709.68	709.68
A_2	322.58	258.06	774.19	193.55	193.55
A_3	64.520	516.13	64.520	387.10	387.10
A_4	64.520	64.520	64.520	64.520	129.03
A_5	64.520	129.03	64.520	64.520	64.520
A_6	129.03	193.55	129.03	193.55	129.03
A_7	322.58	129.03	322.58	64.520	64.520
A_8	322.58	322.58	322.58	516.13	580.64
Optimal Weight in N	299.393	361.335	378.542	340.69 1	349.722
Scaled Fitness	3.492	4.555	26.065	9.359	10.770
Constraint Violation	0.856	0.508	0.001	0.241	0.165

D. Optimal Variables of 25 Bar Truss

Area A_1 of population size 20,30,40, 50 and 60 values are 64.52, 774.19, 516.13, 322.58 and 516. 13 respectively. A_1 value increases and then decreases. Finally, its value from the 60th population size reaches the value of 40th population size. A_2 of population sizes 20,30,50 and 60 remain same except 40th population size. Population sizes 20 and 50 are having same area value A_3 that is equal to 774.19 whereas population sizes 30,40 and 60 are having equal value of 709.68. A_4 value of population size 20 and 50 are 322.58 and 193.55 respectively. A_4 value is the same for population sizes 30, 40 and 60. A_5 is 64.52 in population sizes 20,30,40 and 60 and it reaches 129.03 in 50th population size. A_6 value is 709.68 in all the population sizes except 60th population size and it is 750. A_7 value is 709.68 in all the population sizes except 50th population size and it is 774.19. A8 value is 709.68 in population sizes 20,30,40 and 60. A8 value of population size 50 is 750. Optimal weight value of population sizes 20, 30, 40, 50 and 60 are 815.58 N, 812.14 N, 806.98 N, 844.83 N and 806.98 N respectively. Scaled fitness value from 20,30,40,50 and 60th population sizes are 12.26, 12.31, 12.39, 11.83 and 12.39 respectively. It is observed that there is no constraint violation in each population size.

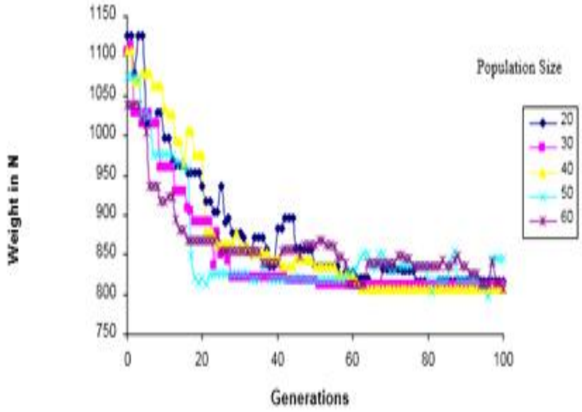

Fig 4. 25 Bar Tower History Generation Using Stress Constraints (Stress Constraint)

E. Displacement constraints of 25 bar truss

Area A_1 value of population sizes 20,30,40,50 and 60 are 727, 806, 684, 386 and 476 respectively. Population sizes 20 and 50 are having the equal A_2 value of 1150 whereas in other population sizes A_2 value becomes 958. A_3 value is 1054 in population size 20 and it is 958 in other population sizes. A_4 is 64.52 in all population sizes except the 60th population size and it is about 145. All population sizes are having the equal A_5 value of 64.52. A_6 value is 958 in the population sizes 20, 30, 40 and 60 and 1150 is observed in the 50th population size. The value of A_7 is 958 in all chosen population sizes except 50th population size. A_8 value of population sizes 20,30,40 and 60 are 958 and it differs from 50th population size value of 1054. Optimal weight value of population sizes 20, 30, 40, 50 and 60 are 1135.91 N, 1078.68 N, 1072.17 N, 1179.17 N and 1069.70 N respectively. Scaled fitness value from 20,30,40,50 and 60th population sizes are 8.803, 9.271, 9.327, 8.48 and 9.348 respectively. Finally, the constraint violation is zero in every population size.

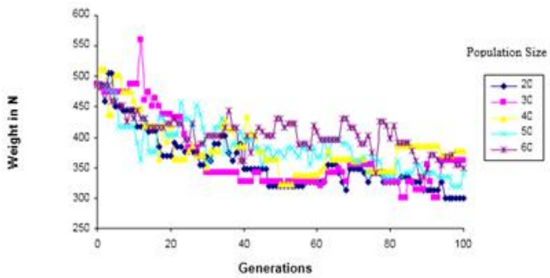

Fig 5. Generation History of 25Bar Tower Using Fuzzy Constraint
(Displacement Constraint)

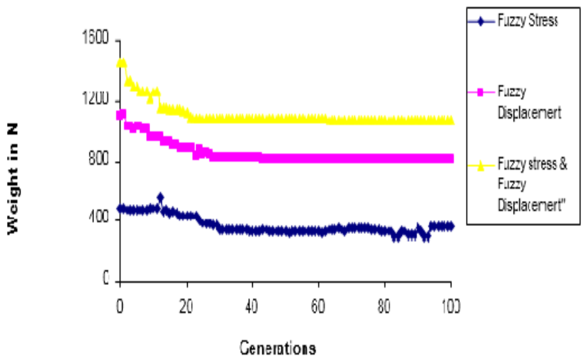

Fig 6. Comparison of Generation History for various Constraints for Population Size 30

Table IV. Comparison of Results for 25 Bar Tower for Various Methods of Optimization for Population Size 30

Areas in mm^2	Genetic Algorithm	Fuzzy Controlled Genetic Algorithm
A_1	645.16	806.0
A_2	1225.80	958.0
A_3	1225.80	958.0
A_4	64.52	64.52
A_5	709.68	64.52
A_6	750.0	958.0
A_7	750.0	958.0
A_8	1225.80	958.0
Optimum Weight in N	2159.51	1078.684
Scaled Fitness	0.689	9.271
Constraint Violation	0.573	0.0

IV. RESULTS AND DISCUSSIONS

Fuzzy constraints are implemented in order to develop an efficient genetic algorithm. Random generation of population has been used at the time of first generation and reproduction. This also applied in crossover and mutation. Area of the towers are represented by the substring and it has been checked with the violation of constraints. If-then rules are used within the limited value.

Fig 6, the population size is 30 and generation history of the 25 bar truss were compared with various constraints. Because of fuzzy controlled genetic algorithm, the error rate is minimized to very low, it is almost near to zero.

The optimal weights obtained by displacement and stress and displacement constraints using the fuzzy genetic algorithm gives different values as shown in Table IV,V,VI.
From Table VII it found that the fuzzy hybrid genetic algorithm yielded lesser weight compared to genetic algorithm and also with zero constraint violation

V. CONCLUSIONS

In this research work, by the application of “if-then” rules in fuzzy gave better result. The comparison between genetic and fuzzy techniques, the fuzzy techniques gave the best result. This has been investigated in 25 bar transmission line tower. Optimal sizing of the same is obtained to meet the design requirements. The performance characteristics are verified with different constraints. Other techniques will be user for the future research work.

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