Multi objective design optimization of machine elements using modified NSGA

Mr.P.Karunakaran
Department of Mechanical Engineering
Sri Krishna College of Technology
Coimbatore, India

Dr.R.Saravanan, M.E., Ph.D.,
Department of Mechanical Engineering
Sri Krishna College of Technology
Coimbatore, India

***Abstract*—This paper presents the modified Non-dominated Sorting Genetic Algorithm technique for multi objective design optimization of 2-bar truss design and simple gear train. The modified algorithm reduces computational time and effort as compared to original algorithm.**

***Keywords*—Design; Optimization; Genetic Algorithm; NSGA; 2-bar truss; Simple Gear train**

I. INTRODUCTION TO OPTIMIZATION

Achieving products with minimum cost and maximum quality is one of the challenges in industries. Optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function. In addition to the functional requirement if certain objective function is considered then it is called optimum design. Minimizing the effort required or Maximizing the benefits or Combination of both are the examples of optimization. Optimization techniques are used to find the maximum or minimum value of a function.

II. OPTIMIZATION TECHNIQUES

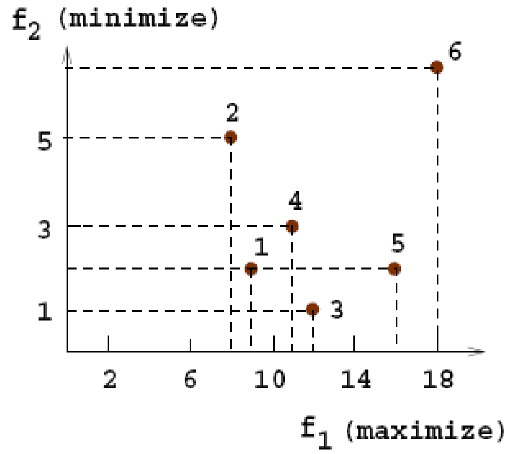
1. Genetic / Evolutionary Algorithm
(Non-Conventional Method)

Genetic algorithms are a part of evolutionary computing, which is a rapidly growing area of artificial intelligence. As you can guess, genetic algorithms are inspired by Darwin's theory about evolution. Simply said, solution to a problem solved by genetic algorithms is evolved. Genetic Algorithms mimic the principles of natural genetics.

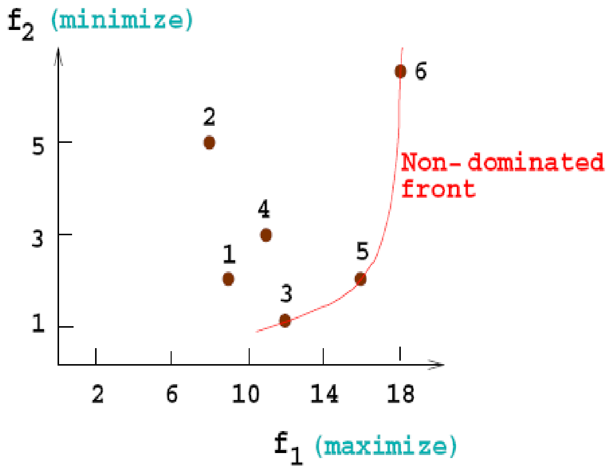
Genetic operators are reproduction, crossover and mutation. During reproduction, first occurs recombination. Genes from parents form in some way the whole new chromosome. Crossover selects genes from parent chromosomes and creates a new offspring. The simplest way how to do this is to choose randomly some crossover point and everything before this point copy from a first parent and then everything after a crossover point copy from the second parent. After a crossover is performed, mutation takes place. This is to prevent falling all solutions in population into a local optimum of solved problem. Mutation changes randomly the new offspring.

2. Non-dominated Sorting Genetic Algorithm

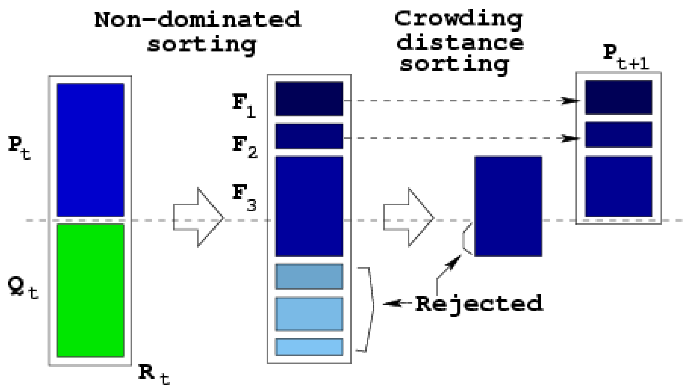
Relates to the concept of domination
$x^{(1)}$ dominates $x^{(2)}$, if
$x^{(1)}$ is no worse than $x^{(2)}$ in all objectives
$x^{(1)}$ is strictly better than $x^{(2)}$ in at least one objective
Examples:
3 dominates 2
3 does not dominate 5



P'=Non-dominated (P) Solutions which are not dominated by any member of the set P
Pareto-Optimal set = Non-dominated(S)
A number of solutions are optimal



Elites are preserved, Non-dominated solutions are emphasized and NSGA-II can extract Pareto-optimal frontier

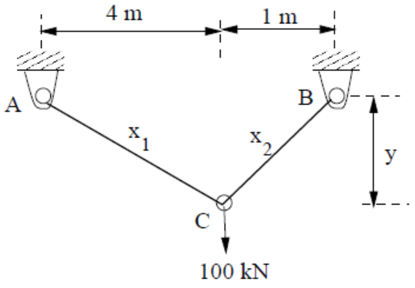


III. TWO-BAR TRUSS DESIGN

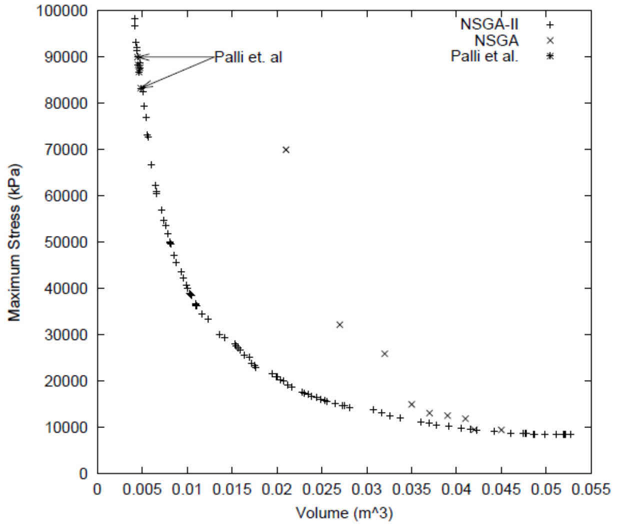
The Objective of 2-bar truss design is to minimize the volume and minimize stresses in each of the two members.

$$\begin{aligned}&\text{Minimize } f_1(\boldsymbol{x}) = x_1\sqrt{16+y^2} + x_2\sqrt{1+y^2}\\ &\text{Minimize } f_2(\boldsymbol{x}) = \max(\sigma_{AC}, \sigma_{BC})\\ &\text{subject to } \max(\sigma_{AC}, \sigma_{BC}) \le 1(10^5)\\ &\qquad 1 \le y \le 3 \quad \text{and} \quad \boldsymbol{x} \ge \boldsymbol{0}\end{aligned}$$

$$\sigma_{AC} = \frac{20\sqrt{16+y^2}}{yx_1} \qquad \sigma_{BC} = \frac{80\sqrt{1+y^2}}{yx_2}$$



Optimized solutions obtained using the NSGA and NSGA-II

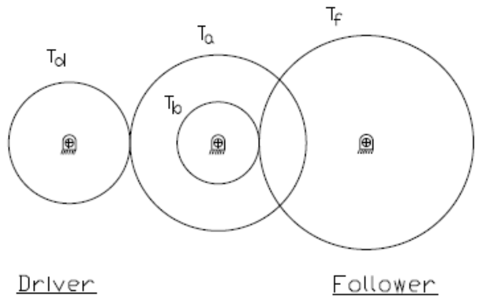


NSGA-II solutions range (0.00407 m^3, 99755 kPa) and (0.05304 m^3, 8439 kPa).

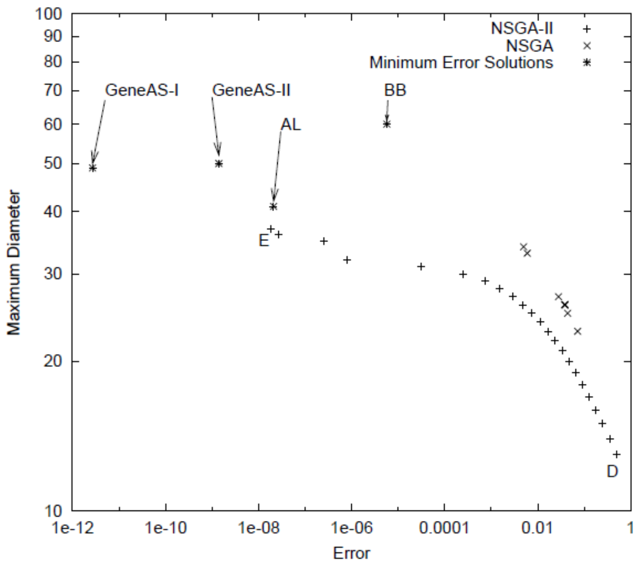
IV. GEAR TRAIN DESIGN

The objective of gear train design is to minimize the error between the obtained gear ratio and a required gear ratio of 1/6.931.
Design Variables $(x_1,x_2,x_3,x_4) = (T_d,T_b,T_a,T_f)$.

$$\begin{aligned}&\text{Minimize } f_1(\boldsymbol{x}) = \left[\frac{1}{6.931} - \frac{x_1x_2}{x_3x_4}\right]^2\\ &\text{Minimize } f_2(\boldsymbol{x} = \max(x_1,x_2,x_3,x_4)\\ &\text{Subject to } 12 \le x_1,x_2,x_3,x_4 \le 60,\\ &\qquad \text{all } x_i\text{'s are integers.}\end{aligned}$$



Optimized solutions obtained using the NSGA and NSGA-II



NSGA-II solutions range

Solution	x_1	x_2	x_3	x_4	Error	Max. Diameter
E	12	12	27	37	$1.83(10^{-8})$	37
D	12	12	30	30	$2.47(10^{-4})$	30

V. PROPOSED ALGORITHM

The multiple objectives of the design problem will formulated as combined objective function. By minimizing the combined objective function the computational time and effort will be reduced as compared to original algorithm.

Formulation of COF

$COF = (OF_1/MOF_1)*WFN + (OF_2/MOF_2)*WFN$

Where,

COF = Combined Objective Function

OF = Objective Function

MOF = Maximum of Objective Function

WFN = Weightage for Normalization

VI. RESULTS

C Language coding obtained from Kanpur Genetic Algorithms Lab used to solve the design problems. The Optimized results will be compared with NSGA-II results.

VII. FUTURE SCOPE

This modified Non-dominated Sorting Genetic Algorithm can be applied to solve complex engineering problems and real time engineering problems in order to obtain optimum results.

VIII. REFERENCES

1. Kalyanmoy Deb, Amrit Pratap, and Subrajyoti Moitra "Mechanical Component Design for Multiple Objectives Using Elitist Non-Dominated Sorting GA" Technical Report No. 200002
2. Rajkumar Roy, Srichand Hinduja, Roberto Teti "Recent advances in engineering design optimisation: Challenges and future trends" 57 (2008) 697–715
3. Aimin Zhou, Bo-Yang Qu, Hui Li, Shi-Zheng Zhao, Ponnuthurai Nagaratnam Suganthan , Qingfu Zhang "Multiobjective evolutionary algorithms: A survey of the state of the art" 1 (2011) 32–49
4. Yusliza Yusoff, Mohd Salihin Ngadiman, Azlan Mohd Zain "Overview of NSGA-II for Optimizing Machining Process Parameter" 15 (2011) 3978 – 3983
5. Dongho Jeong, Jongsoo Lee "Electrode design optimization of lithium secondary batteries to enhance adhesion and deformation capabilities" 75 (2014) 525–533
6. Biswesh R.Acharya, Chinmaya P.Mohanty, S.S.Mahapatra "Multi-objective Optimization of Electrochemical Machining of Hardened Steel Using NSGA II" 51 (2013) 554 – 560