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Multi-objective fuzzy optimization of space trusses by Ms-Excel

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Abstract

In this study space truss systems were design optimized by using fuzzy sets. For this aim λ formulation was applied. The analysis of the truss system is made with respect to matrix-displacement method. The algorithm of multi-objective fuzzy optimization was formed using the macros of Ms-Excel. A number of design examples are presented to demonstrate the application of the algorithm.
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1. Introduction

Optimization is an important activity in many fields of science and engineering. A lot of modelling, design, control and decision-making problems can be formulated in terms of mathematical optimization. The classical framework for the optimization is the minimization (or maximization) of the objectives, given the constraints for the problems to be solved. Many design problems, however, are characterized by multiple objectives. The first note on multi-criterion optimization was given by Pareto; since, then the determination of the compromise set of a multi-objective problem is called Pareto optimization [1–2].

The engineer often encounters a problem in development of a precise mathematical model of the systems. Vagueness and impreciseness often arise due to poorly defined data, system boundaries, unsatisfactory formulation of design objective and in ability in evaluating the relative importance between the objectives. As the complexity of the systems increases, more assumption are made about its behavior and hence, the ability of the engineering to exactly model the systems in the precise mathematical terms is severely hampered [3]. To model vague and imprecise nature of the design problem, one has to use the fuzzy set theory [3,4].

The fuzzy set theory was originally developed by professor Zadeh and is a beautiful way of describing a natural condition in optimization mathematically. Since, the appearance of the fuzzy theory, some researches and applications have accomplished, such as [3,5]. In one formulation of fuzzy optimization due to Zimmerman [6], concepts from Bellman and Zadeh model of decision making [7] are used for formulating the fuzzy optimization problem. The linear fuzzy membership function [8,9] and nonlinear fuzzy membership function [10–12] for structural optimization are used to represent the fuzzy nature of failure. Rao presented a formulation for the fuzzy optimization of engineering systems involving multiple objective [3].

In this study, design of space truss systems was performed by fuzzy sets. In design multi-objective fuzzy optimal decision was used. Objective functions, volume of the minimum weight and minimum displacement were considered in the numerical examples. The volume of construction weight, displacement, cross-sectional areas, membership degrees, upper and lower limit values of the stress elements were used as constraints.

This paper shows that multi-objective λ formulation of fuzzy engineering systems can be used for optimum design.

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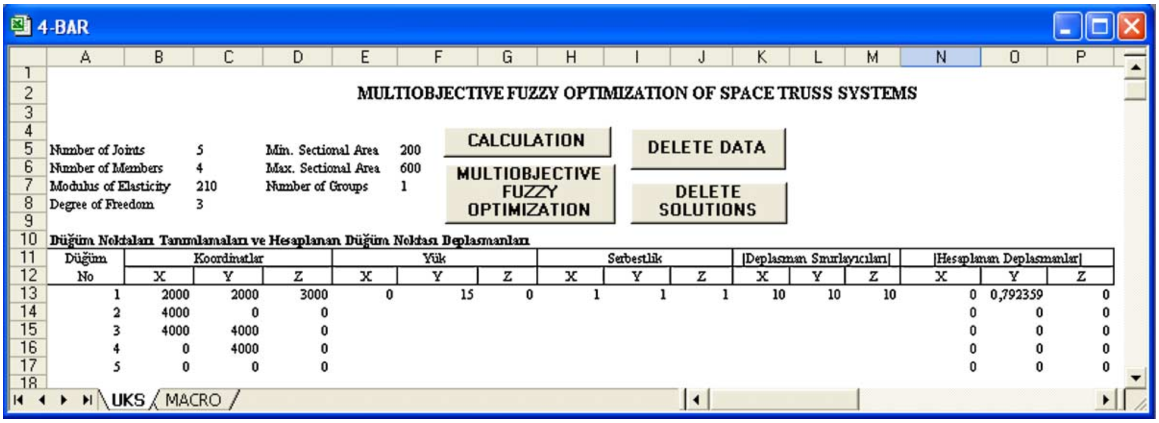

Fig. 1. General information and joint descriptions.

2. Multi-objective fuzzy optimization method developed by spreadsheets tables

2.1. Fuzzy optimization

Fuzzy optimization is the name given to the collection of techniques to formulate optimization problems with flexible, approximate or uncertain constraints and objectives by using fuzzy sets.

Fuzzy optimization problem associates fuzzy input data by fuzzy membership functions. Fuzzy optimization model assumes that objectives and constraints in an imprecise and uncertain situation can be represented by fuzzy sets. In the fuzzy optimization the fuzziness of available resources is characterised by the membership functions over the tolerance range. In the present study objective functions are considered as fuzzy sets and inflows are considered in the form of chance constraints.

2.2. Mathematical model for multi-objective fuzzy optimization

The strategy of the multi-objective optimization techniques adapted is multi-objective fuzzy formulation.

Multi-objective fuzzy optimization problem be stated as follows;

$$\min f(x) = \{f_1(x), f_2(x), \ldots, f_k(x)\}^{\mathrm{T}} \quad (1)$$

subject to

$$g_j^{(l)} \le g_j(x) \le g_j^{(u)} \quad j = 1, 2, \ldots, m \quad (2)$$

where x is the design vector, $f(x)$ is the vector of objective functions, $g_j(x)$ is the jth constraint function, and the superscripts l and u indicate the lower and upper bound values, respectively. Membership degree of the constraint function $g_j(x)$ must be $\mu_{gj}(x) > 0$. The complete formulation is available in Rao's paper [3].

2.3. General objective fuzzy optimization macro

An algorithm which performs optimum design of the space truss systems by spreadsheets was written. Fuzzy sets were added to the algorithm developed and multi-objective fuzzy optimization of space truss systems was carried out.

Multi-objective fuzzy optimization algorithm can be stated as following;

Step 1. First, template table is prepared on spreadsheets as seen in Figs. 1–4.

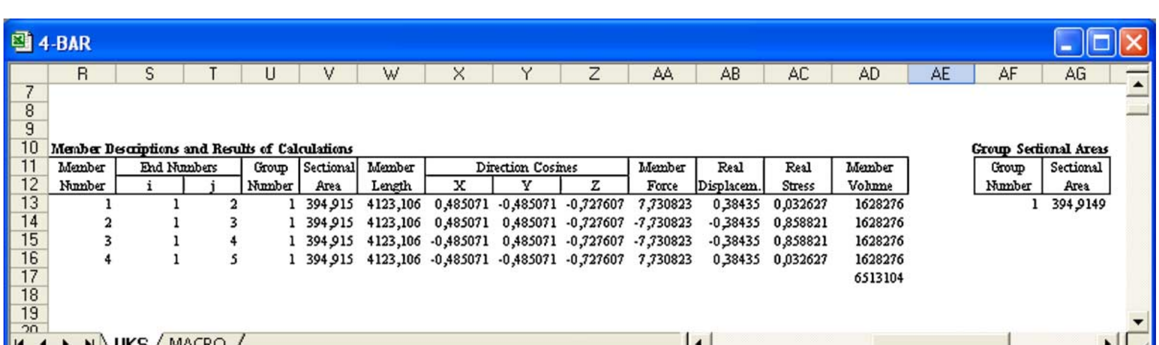

Fig. 2. Member and member group descriptions.

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