Chapter 6
A Short Review on Fuzzy System of Linear Equations Applications

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ABSTRACT

Fuzzy system of linear equations (FSLE) plays a major role in various areas such as operational research, physics, statistics, economics, engineering, and social sciences since the parameters of FSLE are not always exactly known and stable in real-life problems. This effect may follow the lack of exact information, changeable economic conditions, etc. Although there exist many review papers on the solution methods for FSLE, they are not based on the applications. This chapter has attempted to provide a short review on real-life applications of FSLE. In addition, for the common application areas, the fundamental models and the solution methods are presented considering the most cited and leading papers in the literature.

INTRODUCTION

The fuzzy sets has been investigated handling the relationship between fuzzy logic and probability for the perception-based final decision after it was introduced by Zadeh in 1960s. After development of fuzzy set theory, financial, engineering, electrical problems, etc. are reduced to linear equation systems using intervals or fuzzy values. It is also known that differential equations represent many problems in mathematical models and some of these problems can be rewritten as a system of linear equations for solving numerically.

FSLE has important role by using fuzzy modeling considering uncertainty in actual environment. System of linear equations has wide applications that are characterized by the lacking of the sufficient parameter values. FSLE arises in various areas such as social sciences, engineering, image processing etc. Fuzzy mathematics is a better tool than the crisp mathematics for modelling the real life problems. The fuzzy sets/numbers can represent data with indeterminate information. In a fuzzy set, fuzzy numbers are proven to be very suitable for expressing vague, imprecise, uncertain values (Kaufmann & Gupta,

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1985; Hanss, 2005). Thus, to develop the mathematical models in many applications, the information obtained from decision makers may have partial determinacy due to a lack of data, measurement errors or limited knowledge. To overcome these ambiguities, many researchers used fuzzy numbers instead of crisp numbers.

In many FSLEs, some or all of the system parameters are vague or imprecise. If all system parameters (coefficient matrix and right hand side vector) are fuzzy numbers, then the corresponding system of linear equations are named Fully Fuzzy System of Linear Equations (FFSLE). The main intent of FFSLE is to widen the scope of FSLE in scientific applications by removing the crispness assumption on parameters. The most general structure of a FSLE is called Dual Fuzzy System of Linear Equations (DFSLE). Dual forms of FSLE and FFSLE provide modelling real life problems in a more flexible and realistic way. Thus, in this review paper, we focus on dual forms. This advantage of dual systems in the modeling increases the usability and importance of the scope in interdisciplinary research areas.

There is a limited number of works for DFSLE and Dual Fully Fuzzy System of Linear Equations (DFFSLE), while FSLE has a vast literature. The studies involving real life applications of dual systems are encountered rarely (Kocken & Albayrak, 2015). After Friedman et al. (1998) introduced a model to solve a FSLE whose coefficient matrix is crisp and the right-hand side column is an arbitrary fuzzy number vector, in Ma et al. (2000), the authors studied duality in fuzzy linear systems $A\tilde{x} = B\tilde{x} + b$ where A and B are real $n \times n$ matrices. Ma et al. (2000) which can be considered as the first study in the area investigates the existence of the solutions. They claimed that this type of system cannot be replaced by a fuzzy linear system $\left(A - B\right)\tilde{x} = \tilde{b}$, since there is no element v such that $u + v = 0$, for an arbitrary fuzzy number u .

Muzzioli and Reynaerts (2006) studied the FFSLE of the dual form $A_1\tilde{x} + b_1 = B_1\tilde{x} + b_2$. A solution of this system is presented by converting the original $n \times n$ DFFSLE into two crisp linear systems. Abbasbandy et al. (2008) proposed a numerical method based on pseudo-inverse calculation for finding minimal solution of DFSLE. Two necessary and sufficient conditions for the minimal solution existence are given.

The applications of FSLE to other fields such as economic sciences, engineering have been of great interest in recent years. The following presented experiments are provided which illustrate the applications of fuzzy system of linear equations are very supportive motivating within concept. In the following section, after giving brief information about the most common application areas, we intend to present the fundamental models in more detail with some numerical experiments.

One of the most important applications of system of linear equations to electrical engineering is to analyze electronic circuits. The goals are to calculate current flowing in each branch of the circuit and to calculate the voltage at each node of the circuit, which are known Loop Current and Nodal Voltage Analysis, respectively. Another important application of system of linear equations is input-output analysis that is developed by Leontief (Leontief, 1986) who was awarded the Nobel Prize for his work in 1973. Input-output analysis is an extremely effective tool used in more than 70 countries over the world for manufacturing processes optimization, economy condition improvement. Fuzzy set theory can be used to solve economic input-output models. These models are the basis for more elaborate models in part of the world. Let X be a production vector in R^n , which gives output of each sector. An open sector as a non-productive part are listed by demand vector. Fuzzy set theory is used to represent the uncertainties for solving Leontief input output model with fuzzy entries. Considering dynamic nature

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