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Goal programming model: A glorious history and a promising future

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Abstract

In the last 40 years, there has been a marked transformation in the development of new methodologies to assist the decision-making process, especially in the development of procedures in multi-criterion decision-making and in multi-objective programming (MOP). Goal programming (GP) is the most commonly known model of MOP and it is today alive more than ever, supported by a network of researchers and practitioners continually feeding it with theoretical developments and applications, all of these with resounding success. This paper paints a picture summarizing the history of GP and suggests a few areas of research in this era of globalization.

1. Introduction

Who would have expected it? Who would have predicted that goal programming (GP), introduced by Charnes and Cooper in the early 1960s as a simple linear program, would have leaped to such success in the 21st century? Far from being a timid or hesitant leap of success, it is instead a promising jump marked with confidence. Today, GP is alive more than ever, supported by a network of researchers and practitioners continually feeding it with theoretical developments and applications, all of these with resounding success. In fact, GP has hundreds of monographs and scientific papers in its favor, and hundreds of applications covering an impressive number of areas and disciplines. As a bonus, the Internet has also joined in with the emergence of WEB sites and discussion groups on GP.

As is commonly known, GP was born at the start of the 1960s thanks to the contributions from Charnes and Cooper (1961). The first applications quickly demonstrate the GP interest in a number of areas (Charnes et al., 1963, 1968). Later, numerous variants and a number of impressive applications followed (Charnes and Cooper, 1977). Zanakis and Gupta (1985) and later Romero (1986, 1991) and Schniederjans (1995) have itemized hundreds of papers dealing with a wide range of problems.

Given the popularity of this model and the large number of active researchers, international conferences were organized to allow them the opportunity to present their findings. The series of international conferences on multi-objective programming and goal programming (MOP/GP) were

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initiated in 1994 and were solely devoted to provide a forum in which academics and practitioners could meet, and learn about the recent developments. The participants at these conferences, whose common interest is multi-objective analysis, are from various disciplines such as optimization, operational research, mathematical programming and multi-criteria decision aid.

The first MOP/GP conference, initiated and chaired by M. Tamiz, was held at the University of Portsmouth, United Kingdom, in June 1994; the local organizing committee comprised of M. Tamiz, R. Hasham, D. Jones, S. Mardle and K. Mirrazavi. The collection of interesting papers presented at this first MOP/GP conference was published in Tamiz (1996). The second conference, chaired by R. Caballero, was organized by the University of Malaga, in Torremolinos, Spain, in May 1996. Other members of the local Committee were P. Lara, J.M. Cabello, M. Gonzalez, L. Rey and F. Ruiz. The refereed papers presented at the second MOP/GP conference can be found in Caballero et al. (1997).

The third conference was held at Université Laval in Québec City, Canada in May–June 1998, and was chaired by J.-M. Martel and B. Aouni with O. Kettani, A. Guitouni and B.L. Khuong as members of the local organizing committee. A broad range of topics were covered during these conferences such as data envelopment analysis, MOP/GP, applications of MOP/GP, fuzzy sets and MOP/GP, artificial intelligence and MOP/GP, neural networks and MOP/GP and interactive MOP/GP.

The rest of this editorial is structured as follows. In Section 2, we will present the history of GP throughout its 40 years. Section 3 introduces the papers presented in this special issue. By way of a conclusion, we will characterize the concept of collective decision-making in the context of our era of globalization, including the new challenges facing the researchers and practitioners in GP.

2. Goal programming: 40 years of history!

The GP is one of the many models which have been developed to deal with the multiple objectives decision-making problems. This model allows taking into account simultaneously many objectives while the decision-maker is seeking the best solution from among a set of feasible solutions.

According to Hwang et al. (1980) and Evans (1984), the variants of GP could be classified into four categories depending on when we introduce information regarding the decision-maker's preferences. These categories are as follows:

- no articulation of the decision-maker's preferences: these methods do not take explicitly into account the decision-maker's preference structure;
- a priori articulation of the decision-maker's preferences by way of utility or value functions;
- progressive articulation of the decision-maker's preferences by using an interactive procedure;
- a posteriori articulation of the decision-maker's preferences where he expresses his preferences for the efficient solutions generated by an algorithm.

Among the best reviews of GP, we cite Ignizio and Cavalier (1994), Romero (1991), Schniederjans (1995), as well as Tamiz et al. (1998). Charnes and Cooper (1977) point out the link between GP and multi-objective optimization. Romero (1985) demonstrated that GP is a particular case of the distance function model. According to Romero (1991), Tamiz et al. (1995), Schniederjans (1995) and Tamiz and Jones (1997), GP constitutes the most commonly known model of the MOP methods. The vast popularity of GP is due, in part, to the fact that it is easy to understand and the fact that it is easy to apply since it constitutes an extension of linear mathematical programming for which very effective solving algorithms are available. Besides, Charnes and Cooper (1977) do not hesitate in qualifying it as the most powerful and easy to use "workhorse".

The methodological contribution to GP continues to increase; however, given the space limitations in this paper, we cannot explain all of them. Let us cite some new developments which could lead to future research and new applications.

The GP model was popularized with the applications by Lee (1972, 1973), Lee and Clayton (1972); Lee et al. (1978) and Ignizio (1978). Among the main applications of the GP we can mention the following: Management of the Reservoir Watershed (Chang et al., 1997), Management of Solid Wastes (Chang and Wang, 1997), Accounting and Financial Resources Management (Cook, 1984; Sharda and Musser, 1986; Aderoba, 1994; Cooper et al., 1997), Marketing and Quality Control (Sengupta, 1981), Human Resources (Price, 1974; Price and Gravel, 1984), Production (Lee et al., 1978; Decro, 1984; Schniederjans and Hong, 1996; Aouni et al., 2000), Transportation and Facility Location (Min, 1988, 1989; Martel and Aouni, 1992; Charnes et al., 1996), Transportation Problems Subject to Budget Restraints (Chalam, 1994), Spatial Studies (Athanassopoulos, 1996), Telecommunications (Sueyoshi, 1996), Agriculture and Forestry (Sinha et al., 1988; Romero, 1991; Pickens and Hof, 1991), Industrial Applications (Rao, 1987a,b; Dhingra et al., 1990; Rao et al., 1992; Gen et al., 1993), Vehicles Park Management (Goghrod et al., 2000) as well as Aviation (Suzuki and Yoshizawa, 1994).

Regarding methodological development, we note many extensions to the GP model such as: weighted GP, lexicographical GP, integer GP, nonlinear GP, stochastic GP, fractional GP, interactive GP, GP with intervals, fuzzy GP, the "MINMAX GP", the "chance constrained GP", and the "GP and constrained regression". According to Romero (1991), Tamiz et al. (1995) and Tamiz and Jones (1997), the weighted GP and lexicographical GP are the most popular and the other GP extensions have few known applications.

Romero et al. (1998) position the GP in relation to compromise programming and the reference point method. Tamiz and Jones (1997) propose an interactive framework for investigating GP models. This framework allows the decision-maker to explore through an interactive process the feasible and efficient regions for solutions. In fact, this framework provides the decision-making process more flexibility where the decision-maker can learn from intermediate solutions and eventually to modify his preferences in order to obtain a more satisfying solution.

Another interesting development is the utilization of GP as a statistical tool for estimation. Recent studies suggest that GP could be an alternative to the conventional statistical methods. In fact, GP provides more flexibility for modeling the estimation process; this flexibility provides the analyst with a platform from which his knowledge and experience can be an input to the parameters'estimation. Among the numerous works in this area, we cite Aouni et al. (1997), Aouni and Martel (2000), Kettani et al. (1998), Oral et al. (1992, 1993), and Oral and Kettani (1988, 1989).

Integer GP is another area with growing popularity. In fact, many applications of GP require the use of discrete variables. Among the works in this field, we cite: Lee and Morris (1977), Markland and Vickery (1986), Lee and Luebbe (1987), Ignizio and Cavalier (1994) and Tamiz et al. (1999).

Despite the GP's popularity, it has also received many criticisms, especially in the case of the aggregation's procedure of deviations related to objectives having incommensurable units of measurement. Martel and Aouni (1990) introduced the concept of satisfaction functions in order to explicitly integrate the decision-maker's preferences and to remedy the incommensurability of the scales. On the other hand, Zeleny (1981) and Hannan (1985) mention the difficulty for the decision-maker to determine goals for each objective, the inaccuracy surrounding these values as well as the phenomenon of dominant solutions.

Apart from a few exceptions, methodological developments of GP and its numerous applications are not supported, as one would expect, with software and tools to assist decision-making process. This limits accessibility to the GP models and its numerous variants, especially for the public at large.

3. Content of this special issue

This special issue of EJOR contains a collection of some papers which were presented at the third international conference on multi-objective programming and GP theories and applications. Its aim is to present some of the latest theoretical and algorithmic developments in the field as well as a useful selection of application papers.

The first paper in this special issue is an interesting case study where the authors T. Sueyoshi and M. Goto use a new slack-adjusted data envelopment analysis model to examine the performance of Japanese electric power generation companies during the period 1984–1993. Through this study, the authors present a practical case where diverse efficiencies and index measures can be used for DEA.

The next paper, written by A. Balbas, M. Ballvé and P. Jiménez Guerra, deals with the density of ideal points in vector optimization. The authors present an interesting literature review concerning the density of the set of ideal points in the set of minimal solutions of strictly positive support functionals. The authors combine the obtained density results with those which already exist in the literature. The ideal points are defined and several characterizations and sufficient conditions for their existence are stated.

In their paper S. Yamada, T. Tanino, and M. Inuiguchi deal with a MOP problem where a convex function is to be minimized over the weakly efficient set. To obtain an approximate solution, the authors propose an inner approximation method which incorporates a branch and bound procedure for optimization over the weakly efficient set. The proposed algorithm terminates after a finite number of iterations. In order to illustrate their method, the authors use an example of portfolio optimization in capital markets where the fund manager looks for solution which minimizes the transaction cost on the efficient set.

In their paper, M. Arenas Parra, A. Bilbao Terol and M.V. Rodriguez Uria propose a new fuzzy GP formulation for the portfolio selection, a model which considers simultaneously the following conflicting objectives: return, risk and liquidity. The values of the goals associated to these objectives are considered as fuzzy. This formulation takes into account the investor's preferences.

The paper written by R. Caballero, T. Galache, T. Gomez, J. Molina and A. Torrico is on "Efficient Assignment of Financial Resources within a University System: Study of the University of Malaga". It is an application of the GP model to allocate financial resources in the Malaga University system. The aim of the decision-making process is to cover the most urgent teaching needs, maximize the research output and improve the quality of the staff. The authors mentioned that the decision-maker of the University of Malaga had been heavily involved during the different phases of the choice process. They also conclude that the developments in their paper can be applied at other Spanish Universities.

The next paper, written by I. Nhantumbo, J.B. Dent and G. Kowero, is another application of the GP model in the management of the Miombo woodland in Mozambique. This study was triggered by the Mozambique Government's policy regarding the management of its natural resources in partnership with rural communities and the private sector. The decision group, composed of people from the local communities, the forestry and tourist industries, represented stakeholders having different interests and priorities. The proposed framework provides the decision-makers with a powerful tool for making choices where economic, environmental and government objectives are expected to be simultaneously satisfied.

The next paper, written by T. Gomez, M. Gonzalez, M. Luque, F. Miguel and F. Ruiz, is on "Multiple Objectives Decomposition–Coordination Methods for Hierarchical Organizations". In their paper, the authors use the weighted GP model to obtain a satisfactory solution for the following three decision-making situations:

1. one decision-maker for the overall goals and one decision-maker for each subsystem;
2. one decision-maker for the overall system;
3. many conflicting decision-makers.

It is assumed that the system under study is composed of a set of interconnected subsystems having their own goals. The proposed mathematical program was solved through an efficient hierarchical technique.

The "Magnitude Adjustment for AHP Benefit/Cost Ratios" is the subject of the next paper. W.C. Wedley, E. Ung Choo and B. Schoner present an application of the analytic hierarchy process in benefit/cost analysis. The benefit/cost approach was widely used to analyze investment projects in order to help organizations make enlightened decisions. Through this approach, the decision-maker considers numerous incommensurable and intangible factors or criteria. The main problem in such a situation is how to aggregate and transform seemingly intangible and uncertain factors. This paper accurately describes the meanness of the benefits/costs analysis and the authors suggest a new procedure intended to guarantee the commensurability of the benefits and cost priorities. This procedure starts from the upper-most level of the hierarchy to compare the overall magnitude of benefits to the magnitude of costs and it ensures that the magnitude adjustment is always made.

F. Ben Abdelaziz and S. Mejri present an "Application of Goal Programming in a Multi-Objective Reservoir Operation Model in Tunisia". In their paper, the authors focus on the problem of water resources in the north of Tunisia and formulated this problem as a multiple-objective stochastic reservoir management program. The aim of this paper was to find the appropriate releases from the different reservoirs in order to satisfy the three following conflicting objectives: demands in water for irrigation and drinking, minimization of the salinity and minimization of the pumping cost. The stochastic GP model was used to solve this problem.

The last paper, written by O. Kettani and K. Khelifi, proposes a GP-based approach for real estate mass appraisal. In their paper, the authors show how GP can be used for statistical estimation purpose. They also present PariTOP, a software that implement the proposed methodology, as well as the results of a large application in Quebec Metro.

4. Conclusion

Globalization of economy, the democratization of collective activities, and the competitiveness requirements continuously challenge the decision-making systems. Firstly, globalization of the economic activities expose the enterprise to a multitude of political, economic and social systems situated throughout the world. The democratization of collective activities involves more people and groups in the decision-making process. The competitiveness requirements and the rationalization lead to out-sourcing strategies. Finally, the networking, the virtual enterprise being the ultimate reality, greatly increases the number of partners, each having its own set of values, and each pursuing specific objectives and having its own constraints. The combination of these different factors leads to, on the one hand, an increase in the number decision-making centers with whom the enterprise must maintain relationships and, on the other hand, a significant change in the nature of the relationships which become more and more transparent, more democratic and more cooperative.

The multiplicity of the decision-making centers renders the negotiating process more complex. Enterprises not having sufficiently prepared to face the situation could have the tendency to adopt avoidance strategies which, in fact, do not allow them to seize the opportunities presented by the globalization of activities and business networks. As with any other game, individual gains depend not only on the objective characteristics of the game, but also on the players' perception of these characteristics and the players' ability to function within the complexity of the situation, to understand the rules of the game, to anticipate the behavior of other players and to identify and maximize the opportunities for collaboration.

The complexity of the decision-making processes clearly challenges managers as well as researchers to focus on models and tools which help them to take decisions encompassing the process of collective decision-making in the context of a network of enterprises, and which accentuate consensus-based approaches. The GP model could be a powerful tool, allowing to model the collective decision-making process adapted to the context of globalization, competitiveness and networking. This model would allow an explicit integration of the stakeholders with the goal of developing satisfactory solutions. In this context, it is especially important to develop a technological environment allowing the stakeholders to manage their collective decisions in an efficient and user-friendly manner.

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