JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Artificial Intelligence for Multi-Level Decision Making Mathematical Models in the Era of Big Data

Savita Mishra
The Graduate School College For Women, Jamshedpur, Jharkhand, India.
Kolhan University,Chaibasa, Jharkhand, India.
e.mail:savitamishrajsr@gmail.com

Abstract: This research explores the role of Artificial Intelligence(AI) in enhancing decision-making quality, efficiency, and accuracy.AI made especially large strides in recent years, as machine-learning algorithms have become more sophisticated and made use of huge increases in computing power and of the exponential growth in data available to train them.The integration of Artificial Intelligence (AI) into decision-making processes is transforming the way organizations operate across various industries. The study examines both the benefits and challenges associated with AI-driven decision-making multi-level programming problem (MLPP) multi-objective decision making (MODM) mathematical models. AI-based MLPPs solvers can be implemented using: TensorFlow For building deep learning models. By integrating AI techniques, multi-level can be applied more effectively in real-world decision-making, from finance to logistics, evaluate the effectiveness Hybrid Approaches: AI + Traditional MLPP Methods. The article provides concrete examples of how AI is transforming decision making in various fields.
Keywords: AI-driven decision-making, multi-level programming problem (MLPP), multi-objective decision making (MODM) mathematical models, compromise solution, satisfactory solution.

1.Introduction

AI transforms decision-making by providing advanced tools for data analysis, prediction, and optimization. The integration of Artificial Intelligence (AI) into decision-making processes is transforming the way organizations operate across various industries.MLPP has been long recognized as an important decision-making problem. Mathematical programming methods to solve such problems trace back early in the development of linear programming. Organizations are generally based on the multi-level decentralized hierarchical system. This ensures smooth running of the organization and proper execution of its policies. The latest generation of AI advances[1,2,8] including techniques that address classification, estimation, and clustering problems, promises significantly more value still.Artificial intelligence , machine learning (ML) and deep learning (DL) being used in conjunction with digital transformation and data science[8]. Robotic Process Automation (RPA) has numerous advantages in terms of automating organizational and business processes with the help of ML and AI. Several concrete real life problems may be put into a MLPP framework. For some of these problems, the Decision maker has to ponder conflicting objective functions. Such competing goals cannot be arbitrarily squeezed within the narrow frame-work of a unique objective function, without running the risk of invalidating all implications that are supposed to be drawn from the analysis[1,2,4,5,6,7,8] contributions to theories and models, which could be used as a basis for more systematic and rational decision making with multiple criteria, has continued to grow at a steady rate.Mathematical models have been constructed for multi-level decision making problems and methods for solving the models are available in many cases. Such methods are usually termed as MLPP techniques. Some of the important MLPPs techniques often used by decision-makers in modern times in business and industry. Decision theory concerns with making sound decisions under conditions of certainty, risk and uncertainty. A number of surveys show the vitality of the field and the multitude of methods which have been developed. MLPP was introduced as a promising and important field of study in the early 1970.

During the last three decades, many methodologies have been proposed to solve bi-level programming problems. Most of these methods are based on concepts of vertex enumeration and transformation approaches. environment, which can attain a satisfaction solution, the number of different ways these components can interact, the number of different types of variables and functions, and the existence of spatial and time dimensions. The scope and range of the problem environment also adds to the complexity of the model. Managing operations becomes more difficult when the number of interactions between and among people and model component increases. That a model is used repeatedly means it is used to analyze issues that are under continuous re-evaluation. For ongoing concerns in the corporate environment, people usually understand the problem, and the model usually functions as a productivity enhancing tool through improved coordination or synthesis of information, and usually, not always, in operations. Complex models are used regularly in public policy discussions A sufficient number of very important classes of problems are actually linear (or, at least, capable of being reasonably approximated by linear functions) so that the study of the linear model is worthwhile. In many situations we formulate nonlinear programming models. Depending upon the problem we apply nonlinear programming method to solve the problem. Many of the operations research techniques involve complex computations and hence they take longer time for providing solutions to real life problems. The developments of high speed digital computers made it possible to successfully apply some of the operations research techniques to large size problems. The developments of recent [8] interactive computers make the job of solving large size problems even more simple because of human intervention towards sensitivity analysis. In 1954, Orchard-Hays wrote the first commercial LP code. This made it possible to do serious computations routinely. Orchard-Hays's work began the synthesis of LP and numerical analysis by addressing the issues associated with concepts such as basis factorization and numerical stability. Recent developments in Interior Point algorithms for LP Commercial Quadratic Programming codes are CPLEX and OSL marketed by Maximal Software. Most of these packages include (mixed) integer, binary or quadratic programs for LP as well as NLP problems.

MLPP as an adaptation of the Scientific Approach
Thus, the procedure for an MLPP study generally involves following some major steps :
* formulating the problem,
*constructing the mathematical model to represent the system under study,
* deriving a solution from the model,
* testing the model and the solution so derived,
*establishing controls over the solution and putting the solution to work-implementation.
Multi-level fractional programming problem (MLFPP) is a relevant topic. MLFPP is a special kind of MLPP when decision makers have fractional objective functions problem. As a matter of fact, many Optimization problems in engineering and economics involve the challenging task of pondering both conflicting goals and random data having fractional objective functions. It is a science-based approach to analyzing problems and decision situations to aid solving such problems and decision-making. It is therefore a practical activity, although based on the theoretical construction and analysis.MLPP is an approach and an aid to problem-solving and decision-making. Its distinctive approach is facts-finding and modeling. It examines functional relations (i.e. functions of a system and their related components) from a system overview. It utilizes interdisciplinary mixed-team approach to solving management problems. It adopts the planned approach (updated scientific method which reflects technological advancement as the computer) to management problems. It helps to discover new problems as one problem is being solved.Operations Research is most fundamentally science-based.It is so by adoption and adapting the scientific approach in analyzing operational decision problems. (These are problems involved in carrying out operations).Operations Research is the adoption and adaptation of the scientific approach.This involves the development of a clear and concise statement of the problem at hand. This gives direction and meaning to other steps. In defining the problem, it is important that the whole system be examined critically in order to recognize all the areas that could be affected by any decision taking. It is essential to examine the symptoms and true causes of the problem when defining the issue. Note that when the problem is difficult to qualify, it may be necessary to develop specific and measurable objectives that may not solve the real problem.This step involves the construction of a suitable model (usually mathematical), which is a representation of the problem at hand. It might be of a functional nature as in linear programming or have a logical structure as in simulation and algorithms.It involves obtaining quantitative data either from existing records or a new survey that

fits well into the constructed model of the problem. Over the past five years, numerous papers have been published examining how AI methods are applied to decision-making processes across various industries.

2.MULTI-OBJECTIVE DECISION MAKING (MODM) and MLPPs

As the name implies , a MODM problem contains more than one objective functions. A MODM problem can be mathematically illustrated as shown below :

$$Max/Min: \quad [z_1(x), z_2(x), z_3(x), ..., z_P(x)]$$

$$subject \quad to$$

$$\sum_{j=1}^{n} a_{ij} x_j (\leq, \geq, =) b_i, \qquad i = 1,2,...,m$$

$$\bar{x} \geq 0.$$

Where, $\bar{x}$ is an $n-$dimensional vector. The problem indicates that there are P numbers of objective functions which are to be maximized or minimized. The problem contains m number of constraints and n number of decision variables.

LINEAR AND NON-LINEAR MULTI-LEVEL PROGRAMMING PROBLEMS

Machine Learning for MLPP Approximation Supervised Learning: AI models are trained on a dataset of solved decision making problems to predict optimal solutions. Regression Models: Predict continuous values for decision variables based on historical MLPP data. Support Vector Machines (SVMs): Used for classification-based LP problems, such as separating feasible and infeasible solutions. AI-based MLPP solvers, various experiments were conducted comparing traditional methods with AI-driven approaches (Neural Networks, Reinforcement, genetic algorithm approach, fuzzy programming approach etc.). The results demonstrate improvements in computational efficiency, scalability, and adaptability to dynamic AI-Based Solution Techniques[1,8].

A MLPP is very similar to the MODM problem but with a major difference. There are several DMs involved in the decision making process in a MLPP, where each DM controls only a few decision variables out of the whole set of decision variables. Conflicting objective functions as occurring in the MODM may occur in a MLPP too. Therefore, some of MODM methods are applicable to solve the MLPPS while accounting for the number of decision variables the DM controls. A MLPP consists of two or more hierarchical levels in descending order of importance while in MODM all objectives may or may not be equally important but are not placed in any level. In MLPPs the DM(s) are essentially cooperative. MLPPs can be categorized as a bi-level programming problem (BLPP), three-level programming problem (TLPP), bi-level decentralized programming problem (BLDPP), three-level decentralized programming problem (TLDPP) etc.

A general MLPP can be represented as :

$$\underset{x_1}{Min/Max} \quad z_1(\bar{x})$$

$$\underset{x_2}{Min/Max} \quad z_2(\bar{x})$$

: : :

: : :

: : :

$$\underset{x_p}{Min/Max} \quad z_p(\bar{x})$$

$$subject \quad to \quad g_i(x) \leq b_i, \quad i = 1,2,....,m; \quad x_1 \geq 0, x_2 \geq 0, ..., x_p \geq 0.$$

where, $z_1(x)$, $z_2(x)$, ... $z_p(x)$ and $g_i(x)$, (i =1,2,….,m,) are objective functions and linear or non-linear constraints respectively.

$\{x_1, x_2, ...x_p\}$ are decision vectors under the control of the upper and the lower level DM.

The manipulation of the model to arrive at the best (optimal) solution to the problem. It may require solving some mathematical equations for optimal decisions as in calculus or linear programming models. It may also be a logical approach or a functional approach which does not require solving a mathematical equation, such as in queuing theory. The optimal solution is then determined by some criteria. This involves determining the accuracy or the completeness of the data used in the model because inaccurate data leads to inaccurate solutions. If the model can adequately predict the effect of the changes in the system, however simple it may be, it is acceptable.This involves determining the implication of the solutions to the system. In most cases, a solution to a problem will result in a kind of action or change in the organization. The implication of these actions or changes must be determined and analyzed before results are implemented.

3.AI in MLPP

AI's role in decision-making has evolved significantly over the past few decades.Initially,

AI applications[8] were limited to rule-based systems designed to automate repetitive tasks. However, advancements in machine learning and data analytics have expanded AI's capabilities, allowing it to support complex decision-making processes Reinforcement Learning (RL) for LP Optimization. Markov Decision Processes (MDPs): LP problems are modelled as sequential decision-making tasks where an AI agent learns to optimize decisions. Policy Gradient Methods: AI models learn optimal MLPP solving strategies through trial and error. Deep Q-Networks (DQN): Used to approximate the best MLPP-solving actions in large-scale optimization problems. Artificial intelligence is enhancing conventional research techniques rather than replacing them, opening up new avenues for scale, accuracy, and understanding. In the humanities and social sciences, where interpretation and subtlety are crucial, artificial intelligence (AI) offers supplementary techniques that can reveal patterns and structures in ways that improve rather than impair human judgement. A revolutionary change in the creation, verification, and application of knowledge across disciplines is represented by the incorporation of Artificial Intelligence (AI) into research technique. AI is changing academic research's conceptual underpinnings and instruments, from hypothesis development to data analysis, from qualitative coding to extensive experimentation.

The changing nature of research design in the era of artificial intelligence has been examined in this work, which also describes how AI methodologies assist mixed-methods, qualitative, and quantitative research. In addition to tackling the crucial issues of interpretability, validation, resource intensity.AI-powered multi-level solvers significantly improve optimization efficiency, scalability, and adaptability, making them ideal for solving complex, high-dimensional, and dynamic problems. By integrating AI techniques, multi-level can be applied more effectively in real-world decision-making, from finance to logistics, evaluate the effectiveness Hybrid Approaches: AI + Traditional MLPP Methods. A combination of AI and classical MLPPs methods can improve efficiency and solution accuracy: AI-Accelerated methods[9]. Implementation Frameworks-Gurobi/CPLEX: Traditional LP solvers used for hybrid AI-LP approaches. OpenAI Gym: Used for reinforcement learning based.

4.Discussion:

*AI predicts optimal pivot steps to reduce computational complexity. Neural-Augmented Interior-Point Methods[8].

*Model Training and Evaluation

*Dataset Preparation: AI models are trained using large-scale LP problem datasets[8,9].

*Performance Metrics: Solution Accuracy (compared to traditional MLPP solvers) Computational Efficiency (time complexity and speedup) Generalization (ability to solve unseen LP problems)

*Benchmarking Against Traditional Solvers: AI-based methods are compared with classical method to assess performance gains.

*Deep learning models estimate feasible starting points, reducing iterations. Metaheuristic Approaches (Genetic Algorithms, Particle Swarm Optimization): AI-based heuristic search improves LP solutions in dynamic environments.

*Deep Learning-Based LP Solvers Neural Networks: Used to approximate optimal solutions by learning patterns from large datasets.

*Graph Neural Networks (GNNs): Represent MLPP as graphs, allowing efficient solving of high dimensional LP problems. Autoencoders: Reduce the complexity of MLPPs by compressing features before solving.[8]

*Scalability Issues:As the number of variables and constraints increases, traditional LP solvers become computationally expensive. Largescale LP problems in logistics, finance, and supply chain management require faster solutions[8]

* **High Computational Complexity**:

The Simplex method has an exponential worst-case time complexity. Interior-Point methods require significant memory and computation power for large

The National Institute of Standards (NIST), part of the U.S. Department of Commerce, defines four principles of explainable artificial intelligence:

- An AI system should supply "evidence, support, or reasoning for each output."
- An AI system should provide explanations that its users can understand.
- **Explanation accuracy.** An explanation should accurately reflect the process the AI system used to arrive at the output.
- **Knowledge limits.** An AI system should operate only under the conditions it was designed for and not provide output when it lacks sufficient confidence in the result.

5.Conclusion

AI has been in existence for over six decades[9]. The rise of super computing power and Big Data technologies appear to have empowered AI in recent years. The new generation of AI is rapidly expanding and has again become an attractive topic for research. By integrating AI techniques, multi-level can be applied more effectively in real-world decision-making, from finance to logistics, evaluate the effectiveness Hybrid Approaches: AI + Traditional MLPP Methods. This research explores the role of AI in enhancing decision-making quality, efficiency, and accuracy[8] and The Role of Artificial Intelligence in Decision-Making Processes.Linear Programming (LP) is widely used for optimization in various fields, but traditional methods such as the Simplex algorithm and Interior-Point methods face several challenges such as; Many of the operations research techniques involve complex computations and hence they take longer time for providing solutions to real life problems. The developments of high speed digital computers and AI made it possible to successfully apply some of the operations research techniques to large size problems. The developments of recent interactive computers make the job of solving large size problems even more simple because of human intervention towards sensitivity analysis. In 1954, Orchard-Hays wrote the first commercial LP code. The study aims to provide valuable insights for business leaders, policymakers, and academics, contributing to a deeper understanding of AI's impact on modern decision-making and offering guidance on navigating the complexities of AI integration. This made it possible to do serious computations routinely.

6. References

1. Adams, R. G. (2020). The impact of artificial intelligence on decision-making processes in healthcare. Journal of Healthcare Management, 65(3), 187-195.

2. Bostrom, N., & Yudkowsky, E. (2014). The ethics of artificial intelligence. In E. Zalta (Ed.), The Stanford Encyclopedia of Philosophy (Winter 2014 Edition). Stanford University.

3. Brynjolfsson, E., & McAfee, A. (2017). Machine, platform, crowd: Harnessing our digital future. W. W. Norton & Company.

4. Chui, M., Manyika, J., & Miremadi, M. (2016). Where machines could replace humans—and where they can't (yet). McKinsey Quarterly, 2, 10-19.

5. Davenport, T. H., & Ronanki, R. (2018). Artificial intelligence for the real world. Harvard Business Review, 96(1), 108-116.

6. Diakopoulos, N. (2016). Accountability in algorithmic decision making. Communications of the ACM, 59(2), 56-62.

7. Katsoulacos, Y., & Naim, M. (2018). Artificial intelligence: A guide to intelligent systems. Prentice Hall.

8. Kumar B. R. etl.,(2024). The Role of Artificial Intelligence in Decision-Making Processes, African Journal on Biological Sciences Afr.J.Bio.Sc. 6(6) (2024) 6344-6362 ISSN: 2663-2187

9.Yanging Duan etl.(October 2019). Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda, International Journal of Information Management Volume 48,Pages 63-71.