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Artificial Intelligence In Operations Research: Bridging The Gap Between Theory And Practice

Dr. Rajendra Singh

Associate Professor, HOD Department of Mathematics, Off. Principal MBP.G. College, Dadri, G.B. Nagar

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ABSTRACT

The rapid development of artificial intelligence (AI) strategies has unfolded new opportunities to revolutionize various fields, consisting of operations research (OR). This survey paper explores the mixing of AI in the OR manner (AI4OR) to beautify its effectiveness and efficiency throughout a couple of tiers, which include parameter generation, model formula, and version optimization. By providing a complete evaluate of the ultra-modern and examining the capacity of AI to convert OR, this paper ambitions to inspire similarly studies and innovation within the development of AI-stronger OR strategies and tools. The synergy between AI and OR is poised to drive big advancements and novel answers in a mess of domain names, in the long run leading to more powerful and green selection-making.

INTRODUCTION

Artificial Intelligence (AI) is remodeling Operations Research (OR) by way of improving techniques and fixing complex issues greater effectively. AI strategies provide new approaches to tackle conventional OR demanding situations, allowing greater adaptive, predictive, and automated answers. Both the Artificial Intelligence (AI) community and the Operations Research (OR) community are inquisitive about growing techniques for fixing hard combinatorial troubles, in particular within the area of planning and scheduling. AI techniques encompass a wealthy series of information illustration formalisms for handling an extensive style of actual-world problems. Some examples are constraint programming representations, logical formalisms, declarative and functional programming languages consisting of Prolog and Lisp, Bayesian models, rule-primarily based formalism, and many others. The disadvantage of such rich representations is that in well-known they lead to intractable problems, and we therefore regularly cannot use such formalisms for handling practical length troubles. OR, however, has focused on more tractable representations, inclusive of linear programming formulations. OR based totally techniques have tested the capability to discover top of the line and domestically surest solutions for nicely-defined hassle spaces. In well-known, however, OR solutions are limited to rigid fashions with restrained expressive electricity. AI strategies, on the other hand, provide richer and more flexible representations of real-global troubles, helping green constraint-based reasoning mechanisms as well as combined initiative frameworks, which permit the human knowledge to be within the loop. The venture lies in providing representations which can be expressive sufficient to describe actual-world problems and at the identical time making sure excellent and fast answers.

Operations Research (OR) is an interdisciplinary field that employs superior analytical techniques and methodologies to help selection-making approaches in groups, aiming to enhance efficiency, optimize useful resource allocation, and gain favored objectives. By leveraging mathematical models, optimization algorithms, simulation, and statistical strategies, OR aids in addressing complex problems in various domains, which includes logistics, supply chain management, transportation, energy, production, finance, healthcare, and public services, among others.

Artificial intelligence (AI), has been the focus of many peoples' fantasies and the principle plot of technological know-how fiction films for years. However, it's miles now a truth that influences peoples' day by day lives whether or not they may be aware or no longer. AI refers back to the capacity of systems to make computerized records-driven selections without the intervention of humans. The time period AI was defined by means of scientist John McCarthy

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in 1956 and today is the heart of virtually the whole thing in our lives. The cause behind the use of AI is to leverage computer systems and machines to imitate the human mind and carry out selection-making approaches in diverse conditions. As an end result, AI has been implemented in extraordinary areas to expand human intelligence within the best manner.

Operations studies (OR) techniques purpose to assist decision-making processes. Operations studies has been used for years in conventional troubles to find possible answers. OR can be described as "the application of systematic and mathematical systems to observe and look at the troubles that aid us with statistics to take the correct choice". Today, similar to the usage of AI, some of regions have inculcated OR strategies as a part of their selection-making and problem-solving manner to discover greatest solutions. Professionals from varying fields analyse problems, use OR models to enhance answers and minimise risk. Over the beyond few years, tendencies in AI structures have substantially affected the traditional selection-making manner that businesses observe. With an increase in global competition due to the intense tendencies in AI processes, organizations in numerous disciplines have started to apply AI and OR strategies simultaneously to provide a competitive gain. Due to the constant tendencies in AI, OR strategies have additionally been seeing changes in traditional decision-making systems, which has had a positive effect on various fields. Hence there was combined integration of AI and OR strategies in scheduling, day-to-day operations, fault detection, forecasting and so on. That has helped offer brief actual-time selections.

Our studies covers essential tiers inside the pipeline of OR and investigates how AI can help each degree of the pipeline, which offers a holistic attitude and permits us to gain precious insights into the capability synergies among AI and OR. Our key contributions contain two aspects. First, we comprehensively look at the distinctive additives of the OR pipeline at the same time as existing surveys recognition totally on particular components.

Second, we analyze the pipeline as a whole and emphasize the interactions among different components. For instance, the interaction between mathematical version parameter technology and optimization attracted elevated attention from recent literature. Compared with the traditional are expecting-then-optimize paradigm that isolates the 2 components, latest processes started out to explore their interactions.

We survey this rising route, describe existing works, and envision different potential interactions among extraordinary components inside the optimization pipeline. It is critical to clarify that our survey's scope is constrained to strategies that contain the use of optimization software. There is a subset of real-world operational troubles that don't necessitate optimization software program, e.g., unconstraint trouble, time series prediction, or type. For those troubles, stop-to-give up AI answers is possible. However, this survey does not cowl those troubles and their stop-to-stop AI solutions. Kraus et al. (2020) overview the before-noted problems, like predicting the actions of shares, from an operational point of view and the way AI will reap high prediction performance.

Operation Research has benefited from the development in numerous algorithms, computing strength in addition to commercial and open-supply solvers. Solvers are normally relevant to numerous actual-international applications and may resolve large-scale issues correctly. Meanwhile, the advances in AI caused a groundbreaking shift in the improvement of optimization algorithms. Instead of counting on based algorithmic improvement, AI strategies research from records (e.g., past fixing experience), decorate current strategies or even create entirely novel answer techniques. For specific classes of optimization troubles, integration of artificial intelligence into operations research can even reap higher performance than existing solvers. AI4OR guarantees to result in a brand new technology of innovation and performance. This survey paper will delve into the numerous AI techniques that may be employed at each stage of the OR system, imparting a complete assessment of the present day and exploring the capability of AI to transform the manner we approach and resolve complicated decision-making problems. As we hold to develop and refine AI technology, the synergy among AI and OR will certainly cause exciting improvements and novel solution techniques in a large number of domains.

LITERATURE REVIEW

Every piece of machinery or technology that mimics or replaces human intelligence thru the use of computation is taken into consideration to be artificial intelligence (Dhamija and Bag 2020). In recent years OR methodologies have been blended with AI techniques, which include device gaining knowledge of. While OR is used in diverse disciplines to assist locate the most advantageous way to diverse problems, using AI techniques and equipment in various fields allows increase human reliance at the accuracy of OR. Possibilities of successful implementation of artificial intelligence depends largely on big data (Khanra, Dhir, and Mäntymäki 2020). In present day time with facts all around us, the usage of synthetic intelligence is simplest improving the accuracy of reaching most efficient solutions of OR

methodologies. Wide range of areas which include commercial enterprise, finance, agriculture, textile and medication, are now seeing the effect of elevated advances in AI strategies.

(Ivanov and Sokolov 2022) undertook an try and become aware of an interdisciplinary perspective and modelling gear for future supply chains so as to be collaborative with developments inside the AI area. (Jamali, Leung, and Verderber 2020) analysed the utility of OR strategies in conjunction with AI to optimise clinic format. (Sikka, Sarkar, and Garg 2022) investigated and in addition suggested the use of AI in fabric production method to help create extra operational precision and product nice. By using nonlinear regression and picture processing, structural defects may be discovered for this reason assisting to enhance production approaches (Sikka, Sarkar, and Garg 2022). Alternatively, (Sikka, Sarkar, and Garg 2022) outlines the want for AI-based algorithms to assist officials with records offloading and actual-time detection of herbal calamities.

For example, Bengio et al. (2021) cognizance on the combination of AI with combinatorial optimization issues, allowing independent learning and selection-making on a chosen specific set of troubles. Zhang et al. (2022) evaluate how AI assists Mixed Integer Programming (MIP) algorithms together with department-and-certain and heuristic techniques. Lodi and Zarpellon (2017) recognition at the AI-more desirable variable and node choice in the department-and-certain set of rules for MIPs. Schede et al. (2022) survey automated algorithm configuration methods. Kotary et al. (2021) survey two instructions that leverage AI for constrained optimization (CO): AI-augmented CO, which enhances optimization algorithms with AI assistance, and End-to-End CO mastering, in which device getting to know at once predicts the answer of CO. Additionally, some sections in our survey have no longer been mentioned earlier than inside the present surveys. For instance, the version formula and enhancement for unique algorithms like ADMM and column generation.

The smart predict-then-optimize paradigm via Elmachtoub and Grigas (2022) and Amos and Kolter (2017) gathers comments from later choice errors to refine the prediction of parameters. The “included prediction and optimization” paradigm presented with the aid of, Maragno et al. (2021) and Bergman et al. (2021) gives another possible interplay. Recall that the traditional expect-then-optimize paradigm includes first predicting the mathematical model parameters after which deriving an most fulfilling selection.

De Bock et al. (2023) discuss how the integration of explainability and ethical attention can be taken under consideration in AI solutions alongside performance. Furthermore, at the same time as our consciousness is on how AI can boost operational studies, it's miles well known that machine getting to know itself roots deeply in mathematical optimization. Gambella et al. (2021) survey mathematical optimization models provided in numerous AI algorithms, which include category, clustering, deep gaining knowledge of, and Bayesian community shape gaining knowledge of.

ARTIFICIAL INTELLIGENCE IN OPERATIONS RESEARCH

Different authors at some stage in the development of computer technology have committed suitable phrases to define Artificial Intelligence (AI), nearly they all similarly legitimate. In a wide experience, it's been defined thinking about its starting place and the way that intelligence is coded and transferred to devices to perform operations or to optimize techniques for decision-making. In this manner, it's far super the relation with more than one regions, as an instance, Operations Research (OR), which makes use of strategies from mathematical modelling, statistical evaluation and optimization for selection-making. As it is able to be visible, each AI and OR have an intersection in the place known as choice-making, which does no longer imply that that is the simplest component where they go. Even though many regions use AI to resolve their problems, it is and will continue to be a branch of pc technological know-how. AI introduces green algorithms for computational packages to offer an wise human-like behaviour at the same time as acting duties with loads greater precision and velocity; moreover, AI objectives to simulate human behaviours which include reasoning or even creativity, as inside the case of synthetic artwork. AI has made extraordinary progress inside the closing years, which has unfold to many regions and additionally to many one of a kind locations. An location of interest where many domain names, principles, procedures, and so forth. Intersect is OR. For example, OR is normally identified as a sub-area of applied arithmetic, however, it consists of sundry strategies and techniques to improve choice-making and the prized performance of a machine; those encompass optimization, queuing theory and simulation.

OPPORTUNITIES FOR INTEGRATION OF AI/OR

Solving large real-world scheduling problems has so far been almost exclusively the domain of operations research, but recent developments in constraint satisfaction techniques have shown that they can be competitive on real-world problems. The constraint-satisfaction approach brings a novel perspective to planning and scheduling. Constraint-based methods provide a richer representational formalism compared to the traditional OR methods. Furthermore, constraint satisfaction techniques have developed powerful inference methods that lead to efficient variable domain reductions. For example, the constraint programming language ILOG is now being used in actual fielded applications, in areas such as manpower and service scheduling, airline scheduling, cutting-stock in the steel industry, manufacturing scheduling for the auto industry, supply chain management, etc. Companies such as SAP, Peoplesoft, and 12, leading developers of software solutions for managing human resources, accounting, materials management, distribution, and manufacturing, across different industries, combine different optimization techniques such as constraint programming, mathematical programming, and local search methods. These new developments have created a unique opportunity to investigate the integration of AI, primarily constraint-satisfaction methods, and OR techniques. Some key issues are outlined in the following paragraphs.

Hybrid Solvers

This is an important emerging area of research combining CSP techniques with OR techniques. Work in this area began with CLP(R), Prolog III, and Chip, combining constraint satisfaction (CSP) methods with linear programming. The ILOG system integrates a finite domain propagation solver for discrete variables with CPLEX, for continuous variables. Promising results have been obtained using such hybrid approaches, which allow for more powerful constraint reasoning: consistency checking and domain reduction techniques enforce efficient constraint propagation, while linear programming relaxations provide infeasibility, or bounds on the objective function.

Duality

The notion of duality expresses the fact that there are two complementary ways of looking at a problem. Duality is a powerful concept that has been extensively exploited by the OR community in linear programming. Duality can be exploited to solve problems, by considering simultaneously two perspectives — the primal and dual view of the problem. Such approaches, in general, allow for stronger inferences, both in terms of cutting planes as well as variable domain reductions. Recently there have been several promising results in the CSP community using a dual formulation approach (e.g., to solve hard timetabling problems, McAloon et al. 1997, Gomes et al. 1998). However, in general, duality is not yet well understood for problems involving constraints other than inequality constraints.

Problem Structure

In general structured models are easier to understand and compute with. The OR community has identified several classes of problems with very an interesting, tractable, structure. LP, and Network Flow problems are good examples of such problems. OR also exploits the structure of problems during inference by generating, in generally automatically, "cutting planes", which allow for tighter relaxations that are therefore closer to the optimal integer solution. The CSP community, on the other hand, has identified the special structure of several global constraints that are ubiquitous in several problems, which allow the development of efficient constraint propagation techniques for the reduction of the variable domains. In general, however, the notion of structure is very hard to define, even though we recognize structure when we see it. For example, there is not a methodology that shows how to construct good cutting planes. Formalizing the notion of structure and understanding its impact in terms of search is a big challenge for both AI and OR. AI has made some progresses in this area, namely in the study of phase transition phenomena, correlating structural features of problems. For example, in the Satisfiability problem it is known that the difficulty of problems depends on the ratio between number of clauses and number of variables.

Local Search Local search methods or meta-heuristics are often used to solve challenging combinatorial problems. Such methods start with an initial solution, not necessarily feasible, and improve upon it by performing small "local" changes. One of the earliest applications of local search was to find good solutions for the Traveling. There are several ways of implementing local search methods, depending on the choice of the initial solution, types of "local" changes allowed, and feasibility and cost of (intermediate) solutions. There is a great deal of overlap in research on local search by the AI and OR communities, namely in simulated annealing, tabu search, and genetic algorithms. A recent new

area of application for local search methods is in solving NP-complete decision problems, such as the Boolean satisfiability (SAT) problem.

Cutting planes and constraint propagation

OR's inference method of choice, during search, is "cuts". "Cuts" or "cutting planes" are redundant constraints, in the sense that they do not eliminate feasible solutions. However, although these constraints are redundant in terms of the solution, they can play a major role during the search process. A classic example of the importance of cutting planes involves the pigeonhole problem: by adding the appropriate redundant constraints to a linear programming formulation, its relaxation immediately returns infeasibility. Without such redundant constraints, the results of the LP relaxation are useless. The OR community has developed several techniques for the generation of cuts, but, in general, it is not clear how to construct such cuts. The CSP's community, on the other hand, mainly relies on domain reduction techniques for inference during search. A very successful strategy is to exploit the structure of special constraints and treat them as a global constraint. Some examples of such propagation methods are the constraint that guarantees that all elements of a vector are different (all-different constraint) and the constraint that enforces that certain values occur a given number of times in a given vector of variables (cardinality constraint). The implementation of such constraints is an interesting use of Network Flow algorithms.

Robustness

Ideally, we would like to find not only good but also robust solutions. The intuition behind robustness is: given a set C of changes to the initial formulation of the problem instance, a solution A is more robust than solution B, w.r.t. set C, if the number of changes required to fix solution A is less than the number of changes required to fix solution B. There are very few results on the study of robustness. Most results emphasize generation of solutions from scratch completely ignoring issues on robustness. This is an area that requires substantial research, starting with a good definition of the notion of robustness.

AI TECHNIQUES IN OR

- **Machine Learning (ML):** Algorithms that analyze from facts and improve their performance over the years without being explicitly programmed. Includes supervised mastering, unsupervised getting to know, and reinforcement gaining knowledge of.

- **Deep Learning:** A subset of ML that uses neural networks with many layers to version complex styles and representations. Applied to tasks like image reputation, herbal language processing, and time-collection forecasting.

- **Optimization Algorithms:** AI techniques like genetic algorithms, simulated annealing, and particle swarm optimization are used for fixing complex optimization issues.

- **Natural Language Processing (NLP):** Enables machines to recognize, interpret, and generate human language. Useful for automating duties related to text records and conversation.

- **Reinforcement Learning (RL):** An approach in which an agent learns to make decisions by receiving rewards or penalties. Applied to dynamic and sequential choice-making problems.

PRELIMINARY: AI TECHNIQUES

There are two important demanding situations in operation studies, and AI techniques have the capacity to deal with them. We start through especially introducing these challenges: 1) The complex interaction among selection variables and constraints: Simple linear algebra-based totally heuristics can be capable of identify that the constraint matrix has a block structure, then the authentic hassle may be decomposed into several subproblems, and thus accelerate fixing the optimization hassle. However, whilst the interaction inside the constraint matrix is greater complicated, e.g., extra variables or constraints are coupling with each different, simple heuristics are both now not relevant or get worse the computational overall performance. It is commonplace that a set of optimization troubles share positive traits that cannot be described (or without problems obtained) mathematically. In such conditions, AI gear are greater applicable

and efficient. 2) The computation fee of fixing complicated optimization issues: Many thrilling and practical optimization troubles are NP-hard. Even for polynomial-time solvable issues, e.g., LP and QP, when the issues scale up, the computational time grows quick. Thanks to advances in hardware, software program, and optimization solvers, many optimization problems can now be solved inside suited time frames. However, due to the growth in records availability optimization issues regularly keep growing in terms of scale and complexity that surpass the abilities of current solvers for real-world packages. Thus we need to harness AI strategies to further accelerate and enhance the efficiency of solving OR fashions.

In the subsequent, we present brief intuitions approximately a number of the AI techniques regularly utilized in OR and why they're useful in addressing the demanding situations. We will focus on two key components of AI techniques: 1) the AI models themselves and a pair of) the learning algorithms of these fashions.

1) Commonly used AI fashions encompass Graph Neural Networks and Recurrent Neural Network. GNN excels at coping with the complex interactions in graphs, which include the real-international graphs represented within the parameter generation stage (Elmachtoub and Grigas 2022) and the equal graph representation of LP, QP, or MILP issues inside the AI-pushed optimization level. RNN is able to keeping statistics from previous time steps. When applying RNN to an iterative algorithm, a time step corresponds to an iteration. Many iterative optimization algorithms are commonly sluggish because they need to check one solution in each new release and decide the subsequent solutions to evaluate. An inefficient or suboptimal preference can restrict the optimization development. Given RNN's skill ability with sequential records, it is a beneficial device in such situations.

2) Prominent getting to know algorithms include Reinforcement learning and Imitation Learning. Reinforcement learning offers a way to the undertaking of high computational cost. As previously mentioned, this price often stems from an inefficient or suboptimal selection made in early iterations. To address this, two more demanding situations appear: i) The metrics, like execution time or duality gap, are non-differentiable w.r.t the decisions. Ii) The need for a mastering algorithm that permits lengthy-time period rewards to influence in advance selections, termed as behind schedule rewards. Reinforcement gaining knowledge of correctly meets each those criteria. Imitation Learning is any other strategy for the task of excessive computational fee. By layout, imitation learning emulates expert behaviour. In optimization fields, those "experts" frequently represent computationally intensive methods nicely-documented in the literature. Instead of traditional enter-label pairs as in supervised studying, imitation mastering makes use of country-movement pairs derived from professional demonstrations. The mastering objective becomes the alignment of the model's predictions with the expert behaviour, that is differentiable. Upon of entirety, imitation learning yields a version that swiftly predicts professional behaviour, thereby correctly tackling the computational project.

APPLICATIONS OF AI IN OPERATIONS RESEARCH

Supply Chain Management:

- **Demand Forecasting**: Machine learning models predict future demand based on historical data, seasonality, and trends, improving inventory management and reducing stockouts.
- **Supply Chain Optimization**: AI algorithms optimize routing, scheduling, and resource allocation to enhance efficiency and reduce costs. Techniques include reinforcement learning for dynamic routing and optimization heuristics.
- **Supplier Selection and Risk Management**: AI models assess supplier performance and risks by analyzing historical data, social media, and other sources to make informed decisions.

Transportation and Logistics:

- **Route Optimization**: AI-driven algorithms optimize vehicle routing and scheduling to minimize travel time and fuel consumption. Examples include dynamic routing based on real-time traffic data.
- **Autonomous Vehicles**: AI technologies like computer vision and deep learning are used in the development of autonomous vehicles for logistics and transportation.
- **Fleet Management**: AI optimizes fleet operations by predicting maintenance needs, managing fuel consumption, and improving vehicle utilization.

Manufacturing and Production:

- **Predictive Maintenance**: AI models predict equipment failures before they occur by analyzing sensor data, enabling timely maintenance and reducing downtime.
- **Quality Control**: Computer vision and deep learning are used for real-time quality inspection and defect detection in manufacturing processes.
- **Production Scheduling**: AI algorithms optimize production schedules by considering constraints, demand forecasts, and resource availability.

Financial Services:

- **Portfolio Optimization**: Machine learning models optimize investment portfolios by analyzing market trends, risk factors, and historical performance.
- **Fraud Detection**: AI techniques identify fraudulent activities by analyzing transaction patterns and anomalies in financial data.
- **Credit Scoring**: Machine learning models assess creditworthiness by evaluating a wide range of factors and predicting default risks.

Healthcare and Life Sciences:

- **Resource Allocation**: AI optimizes the allocation of healthcare resources, such as hospital beds and medical staff, based on patient needs and predictions.
- **Clinical Decision Support**: AI systems assist healthcare professionals by providing diagnostic support, treatment recommendations, and personalized medicine.
- **Drug Discovery**: Machine learning models accelerate drug discovery by predicting the efficacy of compounds and identifying potential drug candidates.

Energy Management:

- **Grid Optimization**: AI algorithms optimize the management of energy grids by forecasting energy demand, balancing supply and demand, and integrating renewable energy sources.
- **Energy Consumption Optimization**: Machine learning models optimize energy consumption in buildings and industrial processes by analyzing usage patterns and adjusting settings.

BENEFITS OF AI IN OPERATIONS RESEARCH

Improved Decision-Making:

- **Data-Driven Insights**: AI provides insights and predictions based on data, leading to more informed and accurate decision-making.
- **Adaptive Solutions**: AI models adapt to changing conditions and new information, enabling dynamic and responsive solutions.

Enhanced Efficiency:

- **Automation**: AI automates complex and repetitive tasks, reducing manual effort and increasing operational efficiency.
- **Optimization**: AI algorithms optimize processes and resource allocation, leading to cost savings and improved performance.

Predictive Capabilities:

- **Forecasting**: AI models predict future trends and events, allowing organizations to plan and prepare for various scenarios.
- **Risk Management**: AI helps identify and mitigate risks by analyzing patterns and predicting potential issues.

Scalability and Flexibility:

- **Scalable Solutions**: AI systems can handle large-scale problems and datasets, making them suitable for complex and extensive operations research applications.
- **Flexible Adaptation**: AI models can be adapted to different domains and problems, providing versatile solutions.

CONCLUSION

AI for Operations Research typically focuses on enhancing an individual stage within the Operations Research pipeline. However, exploring interactions between different stages is an intriguing area of study, such as gathering feedback from later stages to refine earlier ones. The smart predict-the n optimize paradigm is one example as a pioneering approach for integrating diverse stages. Under the SPO framework, besides minimizing the objective, an interesting extension is also ensuring feasibility. Relaxing feasibility is a widely recognized technique employed in real-world applications. Its motivation stems from the fact that domain experts often find the response of "impossible to complete the task" unsatisfactory. Instead, they strive to comprehend the reasons for infeasibility and explore avenues to relax constraints slightly, thereby achieving a feasible solution. By incorporating this concept into SPO, it is interesting to let the AI model be capable of predicting parameters or adjusting parameters such that the constraint is feasible.

Artificial Intelligence is revolutionizing Operations Research by providing advanced tools and techniques for solving complex problems, optimizing processes, and improving decision-making. The integration of AI in OR enhances efficiency, predictive capabilities, and adaptability, leading to significant benefits across various domains. However, addressing challenges related to data quality, model interpretability, integration, and ethics is crucial for successful AI implementation in operations research. As AI technology continues to evolve, its impact on OR will likely grow, offering even more innovative solutions and opportunities.

This study was undertaken to understand the extent of the impact of AI and OR applications across different processes and evaluate the current trends to predict future trends in the different areas of social sciences, business, and accounting. With the developments in AI algorithms and their applications in the past, this topic of study has been gaining increasing relevance year on year. AI techniques have been used for years in order to provide a technological advantage. The use of AI to make decisions and operations across various fields for years to come. But the application of AI and OR techniques simultaneously has seen very few implications in real-life studies. Thus, by conducting an in-depth literature review combined with bibliometric analysis, the study has tried to answer what areas are currently being explored in this area, what gaps lie in these areas and further what future areas will AI and OR see growth and usage in.

In conclusion, AI techniques have demonstrated great potential in enhancing each stage of the OR process. More future works are worth exploring the synergy between AI and OR, e.g., utilizing AI to enhance the interactions between different OR stages. This synergy will undoubtedly lead to exciting advancements and novel solution methods in a multitude of domains.

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