CS F407 – ARTIFICIAL INTELLIGENCE

Approximating Multi-Objective Optimization Problems

USING

GENETIC ALGORITHMS, HEURISTIC SEARCH, SIMULATED ANNEALING

NAMES	TEAM MEMBERS ID
Om Narayan	2021A7PS1324H
Akshat Jain	2021A7PS2564H
Kanchan	2021A3PS2185H
Puneet Agarwal	2021AAPS3207H

GROUP NUMBER - 89

1. INTRODUCTION

The objective of our project is to investigate a class of optimization problems known as convex optimization, each of which has more than one objective function. We propose to approximate the solutions to those optimization problems by modeling them as search problems and then implementing evolutionary algorithms to solve them.

Convex optimization is a type of problem that is particularly relevant due to its frequent occurrence in various fields and its ability to be efficiently calculated and solved. Examples of convex optimization problems that have been studied include linear programming and quadratic programming, as well as least squares problems.

Some of the common real world problems include

- The challenge of device size in electronics and chip design lies in the need to accommodate devices/small chips due to their size for the production of a single device/chip. The goal of this exercise is to select devices that meet all of our needs while remaining the most energy-efficient or cost-effective.
- This type of issue is also commonly encountered in the context of statistical learning, such as when it comes to the fitting of data through least squares error.
- It also applies to portfolio optimization, where the aim is to select a portfolio that will reduce the risk associated with fulfilling a client's needs.

When there is a large number of objective functions and a large number of parameters to consider, conventional methods of computing and solving the problem become inefficient. Our goal is to provide a heuristic for the above problem by utilizing genetic algorithms to approximate the solution of these large parameter problems, which will prove to be more efficient than the conventional methods.

It is true that there are numerous circumstances in which approximate solutions are not desirable, however, there are certain areas or applications in which approximate solutions may be feasible and can save time and resources in the process.

Now that the motivations are clear, let's begin with the introduction of convex optimization problems. Let's begin by introducing convex sets.

If $x, y \in S$ *implies* $\theta x + (1 - \theta)y \in S$ *where* $0 < \theta < 1$ *then* S *is a convex set*.

In other words, if any two points in a set are joined, and each point on this line segment is a set, and this property applies to all pairs in the set, then the set is a convex set.

A function f is convex if the following property holds true for every $x,y \in dom(f)$: $f(\Theta x + (1 - \Theta)y) \leq \Theta f(x) + (1 - \Theta)f(y)$; where $0 < \Theta < 1$

So a convex optimization problem is where we find the minimum of a convex objective function over a convex set.

Now let us give a bit of introduction to genetic algorithms.

GAMs are employed to provide the most efficient and superior solutions to optimization and search queries. The distinguishing factor between GAMs and other traditional algorithms is that GAMs are inspired and employ a variety of biological elements, including mutations, selectivity, and crossover.

We will now discuss how to combine these two fields to approximate these multi-dimensional optimization challenges more effectively.

A fitness function is a combination of multiplicative inverse functions that will be considered when constructing a fitness function for a genetic algorithm. This function will be used to determine the performance of an individual in a population against a set of constraints. Additionally, the fitness function will take into account the penalties associated with violations of these constraints.

The first step would be to generate a population of points based on the limits of the variables, which would be derived from the constraints given during problem definition. The exact number of points to generate would depend on the user's needs.

Following this, we will proceed with parent selection, where we will choose the most suitable solutions using various algorithms taught in the classroom, including Roulette wheel and tournament selection.

We will then proceed with the crossover process, in which the selected parents will be crossed over. The exact algorithms for crossover will be developed while the application is being executed.

The next step is the mutation stage, wherein we will modify our solutions in a manner that allows it to exploit and investigate its properties, potentially resulting in an improved solution. The precise process of mutation will be elucidated at the time of implementation of this application.

The next step is survivor selection, where we will determine which data points we would like to send to be analyzed in the following iteration.

As far as possible, we will also attempt to implement parallelism in this application, allowing the entire collection of points to be distributed across multiple processes or threads.

2. LITERATURE SURVEY

(Valentina Cacchiani et al., 2017) This paper provides a branch and bound-based heuristic algorithm for resolving CMO-MINLP problems. These problems comprise non-linear and convex objective functions and a combination of continuous and integer variables. The algorithm calculates an initial set of viable points using the λ-constraint approach. It then applies bounding and Fathoming rules to reduce the search tree. The leaf nodes are resolved heuristically by a weighted sum, equivalent to a Pareto front solution. This algorithm stands out from other heuristics by addressing the unique difficulties of multivariate optimization problems, such as managing sets of non-dominant points and refining procedures to remove dominated solutions. This refinement procedure improves the quality of the set of solutions. The goal of the algorithm is to achieve a balance between computational performance and solution quality in complex multivariate optimization problems. This algorithm is a valuable tool for optimization research and applications.

(Ehsan Naderi et al., 2017) This paper explores using an innovative Artificial Intelligence (AI) and search algorithm, FAHSOPSO-DE, to solve Optimal Power Flows (OPFs) problems. OPFs are a fundamental issue in the operation and control of power systems, as they involve optimizing the generation and distribution of power while considering various constraints. The algorithm is designed to be flexible and adaptable, with a fuzzy interface that allows for the constant adjustment of inertia weights during iteration. It is tested in 18 case studies, covering a range of one-dimensional and 3-dimensional OPFs. The primary objectives of the algorithm are to optimize power generation, reduce costs, and provide satisfactory OPFs based on the preferences of the power system operator, particularly in multisectoral scenarios. The algorithm is found to be remarkably efficient and robust, with a consistently higher execution time and higher solution quality compared to other alternatives. This research provides valuable insights into using Artificial Intelligence and Search Algorithms to solve complex, real-world optimization challenges.

(Matthias Ehrgott et al., 2010) This paper presents a novel approach to the problem of convex multivariate optimization (MONP) with continuously varying objective and constraint functions based on the Benson outer approximation method. It focuses on finding weakly nonsynonymous points within a specific approximation error ε and demonstrates the algorithm using practical examples. The results demonstrate that the method produces high-quality approximations for multivariate optimization problems with continuously varying objectives and constraints. Additionally, the paper provides insight into the practical considerations associated with this approach. Finally, the paper addresses the challenges associated with non-differentiating MONPs and proposes a heuristic approach, though further research is necessary. Overall, the paper contributes to the multivariate optimization field by expanding an existing algorithm to solve convex MONPs effectively.

(EDWARD J. ANDERSON et al., 2017) This paper examines the optimization problem of multiple objectives in the context of noise-influenced functions. It evaluates the performance of various search algorithms in addressing the challenge of optimization of multiple conflicting objectives while also considering stochastic error in function evaluations. An innovative search algorithm is presented that combines contraction operations and perturbations, demonstrating its efficacy in controlled noisy environments where multiple objectives are involved. The study evaluates the algorithm's performance across 11 test problems while emphasizing its capacity to address the complexity of multi-purpose optimization by incorporating disturbances during the contraction process to accelerate convergence.

(Hojjat Adeli et al., 1994) This paper examines the use of genetic search algorithms to solve multidimensional optimization problems in structural design, focusing on space truss tower optimization. These optimization tasks involve determining the optimal cross-section dimensions for multiple element groups within a truss, which must be subject to various external forces, stress limits, and displacement restrictions. The main goal is to minimize the structure's mass while adhering to the prescribed constraints. To address these optimization problems, two different genetic search algorithms, Algorithms I and II, are employed. Algorithm I is a parallelized algorithm that allows for the calculation of objective functions and constraints across multiple processors and is more efficient as the complexity of the structure increases. Algorithm II is marginally less efficient, as it requires sequential steps, such as fitness values aggregation and subpopulation re-organization, but still provides effective optimization results. These algorithms are applied to various illustrative examples of space truss tower designs with varying complexity.

(Roberto Teti et al., 2013) This paper presents a comprehensive analysis of the potential benefits of a Genetic Algorithm (GA) based approach to optimizing cutting parameters in metal cutting operations, using biological evolution as a source of search and optimization. The goal is to reduce production time while meeting various cutting constraints such as tool lifes, cutting forces, and surface finishes. The GA methodology is outlined in the study, which includes initializing an initial population of individuals, evaluating fitness functions, and utilizing genetic operators such as selection, crossover, and mutation. It is important to note that the fitness function is a guiding factor in the search process, and an illustrative example of the optimization process is provided, which shows that the combination of crossover and mutation is necessary for successful optimization. The GA approach offers the potential to reduce production costs, shorten production times, select parameters more flexibly, and improve product quality.

(Amir Hossein Gandomi et al., 2013) This paper proposes a novel approach to structural optimization problems by integrating the Cuckoo search algorithm (CS) with the Lévy flight algorithm (Lévy flights). The CS algorithm has been validated against benchmark structural engineering problems, and has demonstrated superior performance compared to existing algorithms such as Genetic Algorithms or Particle Swarm Optimisation. The CS algorithm consists of three main steps: selecting the best solutions, exploiting the area locally via random walks, and exploring the world from a global perspective through Lévy Flights. CS requires less fine-tuning of parameters than other algorithms, thus providing a robust and general optimization tool. Additionally, CS can be expanded to support multi-objective and various constraints. Research directions in the future include sensitivity and parameter analysis, hybridization with alternative algorithms, and the development of discrete versions of combinatorial optimization algorithms. It is important to note that mathematical analysis is essential for understanding the performance of metaheuristics such as CS.

(Xiaoxia Han et al., 2020) This paper presents a new approach to multivariate optimization (MOP) problems based on the Simulated Annealing algorithm. It has been tested on various optimization functions, both in-constrained and out-of-constrained scenarios, and has demonstrated its superior performance compared to comparable algorithms. The SA component of the algorithm is particularly notable, as it replicates the annealization process in the metallurgy domain, enabling the algorithm to traverse the solution space without relying on local optima. The paper also highlights the importance of parameter selection to achieve convergence and uniform solution distribution and its practical applicability in various domains, such as optimizing industrial processes and estimating quantum parameters. Further research will be conducted to refine the algorithm further and deploy it in industrial production scenarios to address complex multivariate optimization challenges.

(Elias D. Nino et al., 2012) This paper provides an introduction to EMSA, an emergent hybrid metaheuristic for the resolution of multidimensional combinatorial optimization challenges, with a particular emphasis on BTSP. TSP is defined in the problem statement as the minimization of the total cost of a tour whilst adhering to limitations that necessitate a single visit to each city. EMSA combines genetic algorithms with simulated annealing and deterministic swapping to define the search direction by assigning weights to objective functions. EMSA uses simulated annealing to investigate solution neighborhoods while retaining flexibility by accepting sub-optimal solutions at the outset. Experimental results compare EMSA with its predecessor MODS on BTSP instances, demonstrating the superior performance of EMSA against MODS, as measured by various metrics.

(Haiping Ma et al., 2021) This paper presents a Multi-Step Genetic Algorithmic Approach to Constraint Multidimensional Evolutionary Algorithms (CMOAs) designed to resolve Complex Coordinate Polynomial Problems (CMOPs) with complex feasible regions. This approach involves the gradual introduction of constraints at various stages of the evolution process, initially allowing the population to rapidly converge to a variety of feasible regions, taking advantage of the capabilities of the genetic algorithms. The algorithm's flexibility, based on the principles of the genetic algorithm, allows it to be used for a broad range of CMOAs, especially those with complex constraints. Furthermore, we have incorporated constraint sorting and combination techniques to improve the efficiency of the finding of feasible solutions and accelerate convergence, taking advantage of genetic algorithms' capabilities. In empirical testing, the approach has been compared to highly efficient CMOAs in various suites and in real-world conditions. Further research into refined constraint handling techniques, particularly within genetic algorithms, can further improve efficiency and effectiveness.

(Mohimenul Kabir et al., 2023) This paper addresses the fundamental question of evacuation planning in areas prone to disasters, particularly in transportation engineering. Specifically, it presents an evacuation modeling problem that is formulated as a single-objective problem and a multi-objective problem. Single-objective optimization utilizes efficient heuristics-based methods to provide rapid solutions, while multivariate optimization considers conflicting objectives and provides various solutions. The study also includes the development of an automated bus-based simulator for efficient evaluation of proposed route sets. Additionally, heuristics are introduced to reduce evacuation times and balance requirements across multiple routes. The research was conducted on a Halifax city network, and the results demonstrate the efficacy of the proposed optimization models, the simulator, and the heuristics. Improvements to the model are suggested, such as incorporating practical disaster effects, increasing the model's dynamic range to reduce congestion, and expanding it to include both transit and auto evacuation modes. Additionally, GPUs or computing clusters should be utilized to enhance the efficiency of multivariate optimization, and the model should be expanded to include new mutation operations. The simulator could also be improved by including agent-based activities such as accounting for evacuates who miss the bus.

(K.C. TAN et al., 2002) This paper examines how multiple-objective algorithms (including genetic algorithms) can outperform each other against four common problems. We look at the standard performance metrics, like how many useful individuals are in the population, how evenly distributed the population is along the pre-defined front, how much computing power is being used, how resilient the system is to changes, and how well the regions are distributed in dynamic conditions. All in all, the simulations show that no one algorithm outperforms another across all these metrics. It's important to note that feature elements that add to high effort are mostly for problems requiring long-winded function evaluations. These findings suggest that there's potential to combine different feature elements from different methods into a new, optimized algorithm for specific optimization problems, especially when it comes to genetic algorithms.

(Santosh Tiwari et al., 2008) Archive-based MicroGenetic Algorithm (AMGA) is a novel approach to multivariate optimization. It is designed to be efficient with a small population size, while maintaining a large external archive of top-notch solutions. AMGA draws on the best features of existing algorithms and includes an improved strategy for maintaining diversity. Additionally, AMGA enables independent tuning of different algorithm parameters, such as the initial population, archive, and parent population size. This feature allows practitioners to select smaller parent populations, leading to a significantly faster search process. Furthermore, AMGA seeks to reduce the impact of distribution index variations on algorithm performance when crossover and mutation are performed. AMGA outperforms its competitors compared to two object-oriented test problems and achieves comparable results for three goals. This approach is based on two fundamental principles: reducing the need for function evaluations to achieve equivalent convergence and creating an algorithm resistant to changes in tuning parameters; both principles have been significantly improved with AMGA.

(Zhong Liu et al., 2020) This paper presents a novel approach to address the Closed-Loop Supply Chain (CLSC) network problem for Original Equipment Manufacturers (OEMs). It introduces a multi-objective Mixed Integer Programming (MIP) model that concurrently considers cost, carbon emissions, and network responsiveness, particularly emphasizing the electronic CLSC sector. The proposed model's search algorithm employs a multi-objective genetic algorithm based on NSGA-II, aided by heuristic techniques for chromosome decoding. By using a case study in Hunan province, China, the paper illustrates the model's application and reveals insights: when OEMs seek to enhance network responsiveness or reduce carbon emissions, it is necessary to open more distribution and collection centers, albeit at an increased cost. Comparative evaluations demonstrate that the introduced algorithm surpasses existing approaches using the weight-sum technique for fitness assessment. However, future research should explore alternative methods such as epsilon constraint or gap minimization. Additionally, the paper highlights the importance of addressing demand and returns uncertainty and extending the model to encompass multiple recovery schemes and interactions with third parties, making it more versatile for practical implementation.

(Carlos Juiz et al., 2017) This article seeks to address the issue of the allocation of container resources and the elasticity of self-scaling container replicas. A four-objective optimization approach has been proposed to address this issue, incorporating principles derived from genetic algorithms. This approach is based on the uniform distribution of workload along physical machines, the tight distribution of workload along container replicas, the reduction of network overheads, and the improved reliability of the system. This analysis demonstrates that the approach provides a suitable solution for this problem, as it finds optimized solutions within a reasonably large population size of 100 and 200. This approach has been compared to the results obtained with the application of Kubernetes allocation policies. To further explore the implications of this approach, a genetic algorithm has been applied to the problem of container allocation in the cloud. This approach has demonstrated superior behavior, with smaller values for each objective. It is important to note that this article uses a genetic algorithm while retaining the factual content.

(Heng-Yi Li et al., 2023) This study introduces a method of optimization for dry wheel systems, which is based on the use of genetic algorithms. The initial step in the optimization process is developing an analytical model, which is then used to derive objective functions and constraints. The main objective of the model is to reduce the humidity ratio and the speed of regenerative air flow in order to improve dehumidization and overall energy efficiency. Pareto optimization solutions are identified using the genetic algorithm, which indicates that there is no single optimal solution, and five promising cases are then shortlisted. Subsequently, TOPSIS (Multi-criteria Decision-Making System) is applied, considering the primary objectives, heat input, and DCOP to determine the final optimal solution. The study recommends broadening the number of objective and decision variables for optimization possibilities in the future.

(Panigraphy et al., 2021) This research proposes a novel heuristic algorithm to address optimization problems that are not necessarily convex or constrained. The algorithm is divided into two parts, as is the case with any AI problem modeling. The first part focuses on exploitation, using local search methods such as the Lightning search algorithm, including a weight factor and differential evolution algorithm. The second part updates the minimum fitness value for each population row and then provides the final approximate optimal point for the optimization problem. This is the methodology of the differential evolution algorithm, which begins with initialization and then progresses to mutation and crossover. The Lightning search algorithm, on the other hand, utilizes a step leader mechanism and a binary search tree structure. This algorithm begins with an initialization step, updates the channels, maintains the energy values, and updates the position steps. When weights are included, the method employed in this paper, the test channel, is updated using these weighted values. In conclusion, this paper introduces a novel flavor of the lightning search algorithm and then evaluates the framework to be tested on 60 benchmark functions.

(S.Mardle et al., 1999) This paper describes the basic principles of genetic algorithms for the purpose of solving optimization problems. It covers topics such as candidate solution encoding, selection operator, crossover operator, and mutation operator and concludes that genetic algorithms are an effective and useful tool for optimization problems. This paper provides an overview of the various types of genetic algorithms (GA) and their advantages and limitations, as well as their applications in various fields (e.g., engineering, finance, logistics). It also reviews recent research on GA, including parallel processing and hybridization, among other optimization techniques. The paper also discusses the challenges and future direction of GAs and suggests areas of research to enhance their performance and effectiveness, which in turn will lead to improved results. Finally, the paper concludes that GAs are an effective tool for complex optimization problems, and their use is expected to grow as more advanced techniques are developed. Ultimately, this paper concludes that genetic algorithms can potentially revolutionize the field of research.

(P.Merz et al., 1999) This study presents genetic algorithms for the unbounded binary Quadratic Programming (BQP) problem. The BQP problem is characterized by a symmetric matrix Q. For small problems, a generic algorithm with a uniform crossover is sufficient to find optimal or most commonly used solutions quickly. However, for problems with many variables, it is necessary to include local search to achieve high-quality solutions. This BQP algorithm has many applications, including capital budgeting, financial analysis, problems, and machine scheduling. Hybrid genetic algorithms incorporating a simple local search are found to be more effective than those based on either mutation or crossover. The genetic algorithm model comprises various components, such as Fitness Function, Mutation, Crossover, Selection, and Diversification. The hybrid model includes local search, and the resulting algorithms have been demonstrated to be highly successful due to their combination of the benefits of efficient local search for exploiting the vicinity of a single solution and population-based algorithms that effectively traverse the search space. The epistasis of the matrix Q is determined by dividing the number of non-zero entries by the total number of entries. Therefore, the epistasis of a BQP case can be determined simply by calculating the matrix density.

(D.J. Reid., 1996) D. J. Reid's research paper "Genetic Algorithms in Constrained Optimization" provides an overview of the use of genetic algorithms to address the challenging problem of constrained optimization. The genetic algorithms offer a broad range of optimization solutions. The paper and its authors explain how genetic algorithms can be used to investigate for optimal solutions in a range of optimization problems, beginning with their fundamental principles. Subsequently, they discuss the application of genetic algorithms to constrained optimization problems and provide a broad range of methods for addressing constraints in GAs, including penalty functions, repair functions, and adaptive constraint-handling strategies. This research paper provides a comprehensive overview of the utilization of genetic algorithms in the context of constrained optimization, outlining the advantages and disadvantages of its use and the potential areas of future research. Additionally, it covers the application of genetic algorithms to multi-target optimization problems, providing a variety of GA-based approaches to address these issues. In conclusion, this paper is a useful resource for those interested in using genetic algorithms to address optimization problems.

(H Azarbonyad et al., 2014) This research provides a novel solution to the problem of QAP (generally accepted algorithms) by introducing a genetic algorithm. The problem involves assigning facilities to sites in order to reduce the total distance and flow between facilities. The GA-based approach encodes the QAP solutions in permutations, which assign facilities to locations. The fitness function evaluates the quality of the solution, and crossover and mutation are used to generate novel solutions from existing ones. The analysis results compare the proposed GA to simulated annealing, tabu search, and benchmark example (TS) methods, with the GA outperforming the others regarding solution quality and computing time. The results demonstrate that the GA algorithm suits this difficult optimization problem well.

(G wang et al., 2008) This research paper proposes an innovative solution to the linear-quadratic Bilevel Programming Problem (LQBPP), a metaheuristic algorithm combining the simplex method with a genetic algorithm. The paper includes An adaptive mutation operator and a new encoding scheme that enhances the genetic algorithm's convergence rate and search process. The effectiveness of the proposed genetic algorithm is compared with that of other metaheuristics, such as Particle Swarm Optimization (PSO) or Differential Evolution (DE), against a set of benchmark instances, and the results indicate that the proposed genetic algorithm provides better solutions in terms of resolution and computational time. Furthermore, a sensitivity analysis is conducted to determine the robustness of a proposed genetic algorithm under various parameter settings and encodings, and the results suggest that the GA provides superior solutions regardless of the parameters and encodings used. The proposed genetic algorithm is a promising approach to solving LQBPP and can be used to solve other similar optimization problems.

(I Fister Jr et al., 2013) This paper seeks to identify the sources of inspiration behind various search algorithms used to approximate solutions to optimization problems in various fields. To do so, it is necessary to categorize the algorithms into four main categories: swarm intelligence based, whose inspiration is derived from biological forms, physics and chemistry, and complementing algorithms. Swarm-based algorithms are those in which multiple agents are defined with certain rules and interact with one another, resulting in a holistic collection.

(JJ Koliha., 2003) This paper examines the implications of using a finite set of linear equivalences and inequalities to approximate convex functions. It demonstrates that the error rate can be significantly reduced by increasing the number of constraints and describes the relationship between the approximation method and the convex hulls, concluding that the linear approximation's convex hull converges to the original function's convex hull. Additionally, the paper outlines some techniques for selecting subdomains that may lead to more precise results. In conclusion, the study provides a useful framework for estimating convex functions when the number of linear functions is limited. Furthermore, it is possible to apply the method to many convex functions, as it is convergent. Finally, the paper outlines the drawbacks of the method, such as the possibility of the approximation being unique and the fact that the selection of subdomains may influence the accuracy of the approximation.

(R.E. Korf., 1999) This paper provides an overview of the various search algorithms used in the field of Artificial Intelligence (AI). It covers a range of search strategies, including uninformed algorithms such as depth-first search and breadth-first search and informed algorithms such as A* search, heuristic search, tree search, graph search, state space search, and many others. Additionally, it outlines the various heuristic functions implemented and used by informed search algorithms. Finally, it discusses the drawbacks of AI search algorithms, such as their inability to solve complex problems in certain cases and the need for more advanced approaches, such as machine learning and deep learning. Overall, it serves as a useful introduction to the fundamental concepts of search algorithms in AI and provides insight into how they can be applied to various problem-solving scenarios.

(S Mishra et al., 2017) This paper outlines the potential of genetic algorithms (GA) to be used as a powerful and efficient tool for optimizing global problems. It begins with an introduction of GA and its basic concepts, such as encoding, evaluation of fitness functions, selection, recombination, and mutation, and the schemes of GA. It then outlines the challenges of GA, such as premature convergence, violation of solution space, and the techniques to address them. Finally, it concludes that GAs have the potential to be more effective and efficient when combined with other techniques and that further research is necessary to develop such hybrid designs, as they may prove to be the most effective way to solve practical problems.

(V. Colla et al., 2008) This research paper examines the optimization of model parameters for a sophisticated mathematical model used to predict the mechanical properties of steel, in particular UTS and Yield Strength. It compares various optimization approaches, such as gradient descent, simulated annealing, and genetic algorithms (GAs), to GAs. The study involves the tuning of several model parameters to enhance predictions. The results demonstrate that GAs are more efficient than other methods, yielding better parameter values but requiring more computational time. Furthermore, the optimized model yields better predictions for UTS prediction, although UTS prediction still needs to be refined. The study also highlights the versatility of GAs for further model improvements.

(A. Kurpati et al., 2001) This research paper presents and evaluates four improved constraint handling techniques, categorized as CH-I1, CH-I4, and CH-NA, compared to a traditional approach, CH-NA, first developed by Narayanan et al. in 1999. The main focus of the research is to evaluate these techniques against a range of performance indicators, including the frequency of function calls, the distribution of solutions, and the proximity to an optimal solution point. The evaluation uses two real-world engineering design examples: a speed-reducer design and the optimization of an entire fleet of ships. This research paper provides an overview of four enhanced constraint handling approaches, classified under the heading "CH-I1", "CH-I4," and "CH-NA", compared to a conventional approach, "CH-NA" first developed by the team of Narayanan (1999). The study's primary objective is to assess these techniques in relation to various performance metrics, such as the frequency of functional calls, the proportion of solutions distributed, and the relative proximity to an optimum solution point. This evaluation is based on two engineering design examples, one involving a speed reduction design and one involving optimizing a fleet of ships.

(A. Coello et al., 2001) This paper provides an in-depth analysis of constraint handling techniques in the context of optimization algorithms, offering valuable insights and advice for researchers and practitioners alike. The review covers a broad range of methods, from simple penalty functions to complex, biologically-based approaches inspired by immune systems, cultures, and colonies of ants. A common theme throughout the review is the need for constraint handling techniques to be able to demonstrate generalization. The ultimate aim is to achieve scalability across a large number of problems and constraints with little to no adjustment, thus increasing their versatility in addressing various optimization problems.In conclusion, this paper provides an in-depth and authoritative overview of the state of the art in constraint-handling algorithms in evolutionary algorithms. Not only does it emphasize the importance of ongoing research and development efforts in this critical area, but it also emphasizes the need to strike a balance between multiple goals when designing and executing constraint-handling strategies for optimization problems.

(A. Coello et al., 2021) This study introduces EMOA, a multi-objective algorithm designed to solve Equality Constrained Multiple-Objectives Optimization Problems. The key innovation of the algorithm is the inclusion of a Tchebychef-based quadratic penal function in an achievement function, allowing it to approximate the Pareto front (PF) shape and location while considering the feasibility of constraints. COARSE-EMOA generates reference sets that converge to the feasible PF over its evolution period, with a preference for minimizing performance indicators while adhering to constraints. Although it does not always achieve a full feasible PF approximation, the average feasibility ratio indicates a substantial number of viable solution candidates. Future research directions may include the inclusion of a sorted procedure based on Constrained Domination Principles to reduce computational complexity, as well as the exploration of different curve families for the construction of reference sets, which would improve adaptability for problems with irregular Pareto Front shapes. The primary focus of the study is on two and three object-oriented problems with 1 or 2 equality constraints, with the potential for expansion to higher-dimensional EMOA and many object-oriented optimization problems with constraints.

(J. Horn et al., 1994) This paper presents a novel approach to vector optimization based on differential evolution. The method involves the generation of a step using a random mutation process with a Gaussian distribution as the step size. The results of this approach were compared to two established benchmark problems and found to be more efficient than the SPEA (strength pareto evolutionary algorithm). Furthermore, the authors conducted experiments to determine the effects of different crossover rates and mutation rates on the test problems, with the aim of identifying optimal solutions. The crossover rates had a significant effect on the quality of the solutions obtained, with a clear trend that lower crossover rates resulted in a higher number of non-dominant solutions. The authors acknowledge that the parameters chosen in this study have been determined through empirical experimentation, and thus there is scope for further research into how these parameters influence the optimization process. Looking ahead, the authors intend to expand the algorithm's assessment to a wider range of problems. Additionally, they emphasize their interest in the systematic investigation of the chosen parameters and their intention to further develop this promising optimization approach.

(A. H. F. Dias et al., 2002) This paper presents and evaluates a non-numeric sorting genetic algorithm originally proposed by K. Debsa. It is subjected to a thorough comparison against four other algorithms, using two different test problems as reference points. The results demonstrate that NSGA outperforms its competitors, demonstrating its ability to identify multiple predefined solutions. Additionally, the use of NSGA for the SMES challenge demonstrates its ability to solve multi-objective optimization problems in electromagnetism. In particular, this application emphasizes a fundamental observation: the pre-defined front for the team-22 problem must have a convex shape. This highlights the utility and robustness of NSGA in addressing complex optimization problems in this domain.

3.CONCLUSION

In summary, these research papers demonstrate the essential role of Artificial Intelligence (AI) and Search Algorithms in the resolution of complex optimization issues. AI-based approaches, such as Genetic Algorithms, Simulated Annealing, and New Hybrid Algorithms, are essential in the identification of effective solutions for a variety of real-world problems. The combination of AI techniques with Search Algorithms increases their flexibility, effectiveness, and resilience. These approaches are used in a variety of applications, from Power System Optimization and Structural Design to Evacuation Planning and Supply Chain Management. These papers highlight the potential for AI and Search algorithms to not only optimize objective functions, but also to address constraints, preferences and complex, multidimensional optimization scenarios. As technology and computational capabilities advance, this ongoing research provides optimism for the optimization world, where AI-driven algorithms will continue to yield valuable insights and practical solutions for complex problems in a variety of domains.

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