

Enhancing Performance of Intelligent Systems with Genetic Algorithm Optimization

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Problem Statement

Optimization techniques are increasingly being applied in intelligent systems like robotics, real time scheduler and automated control systems to operate effectively in complex environments that are dynamic. Nevertheless, some of these systems continue to encounter issues of poor allocation of tasks, low flexibility, high cost of calculation and poor scalability. These problems lower the performance of the system particularly in cases that involve real-time or multi objective work.

Genetic Algorithms (GAs) have increasingly become an encouraging solution due to their evolutionary search algorithms that make them more accurate and strong in optimization. Recent research indicates that GAs have the capability of enhancing the performance of systems to a great extent. Indicatively, more advanced models of GA have managed to reasonably accelerate the computation and improve the planning of multi-robot systems (Chabane & Guenounou, 2025). Likewise, scheduling methods that are based on GA have demonstrated greater reliability and less response time in multiprocessor systems (Hassan et al., 2025). A hybrid between GA-AI models have also enhanced the convergence and design efficiency in intelligent engineering applications (Sun & Sun, 2025).

Although these are the advantages, there are still a number of constraints. Most of the GA solutions are only validated in simulation studies decreasing their practical application. There are models which are very demanding in terms of computation resources and therefore cannot be used on resource constrained systems. Also, the current methods are usually developed to cover specific areas with little applicability to various applications of intelligent systems.

Thus, there is an evident necessity to conduct a study that would help to understand how GA optimization could be further developed and adjusted to enhance the performance, scalability, and applicability in the real-life settings of intelligent systems. Sealing the gap will help in creating more efficient, flexible and adaptive next generation intelligent technologies.

Research objectives

Primary Objective

To explore and increase the efficiency of genetic algorithm optimization methods in the better performance, flexibility, and scalability of intelligent systems.

Specific Objectives

- To examine the problematics and shortcomings of the current optimization approaches applied to smart systems.
- To assess the effectiveness, flexibility, and improvement of performance the different GA-based optimization models that have been reported in current literature.
- To develop an optimal GA-based system that cuts down on the existing constraints of the system namely high computational cost, domain specificity and scalability.
- To present the conceptual or applied solution explaining why an improved GA optimization solution can be applied to perform intelligent systems in various fields.
- To make a comparison of the suggested GA-based solution to the existing optimization methods to identify the relative effectiveness of the first.

Literature review

This study addresses the topic of genetic algorithm (GA) optimization to improve the functionality and flexibility of intelligent systems. An overview of six peer-reviewed articles in 2022-2025 gives a profound insight into existing methods, applications, and issues related to this sphere.

Chabane & Guenounou (2025) proposed the initial research named two-stage enhanced genetic algorithm (EGA) which is intended to designate the optimal task allocation and planning in heterogeneous multi-robot systems. The suggested EGA is designed by using domain-specific chromosome encoding of the capability constrained task allocation at the first stage, and the local route refinement at the second stage to reduce traveling distances and enhance load balancing. Compared to other common optimization frameworks such as: Mixed Integer Linear Programming (MILP), Particle Swarm Optimization (PSO), and common single-phase GA, the EGA was found to obtain nearly optimal outcomes with an average optimality gap of less than 1.5 per cent and lower computational times of up to 90 per cent. This scalability indicates the complexity and real-time industrialization of GA. The possibility of a dual-phase design makes the study a considerable strength of the methodology since it gives the study the balance between global search and local optimization, but the study is also limited due to the use of simulation but not the physical validation to generalize the study results. However, it provides a strong background on how GAs may be incorporated in robotic coordination and intelligent automation scenarios.

The second article Naaman et al (2025). provides an overview of GA methods and their general optimization uses. The authors introduce GAs as computational models of biological evolution which work with the help of selection, cross-over, and mutation. The review is across various fields of expertise, and it demonstrates the versatility of GAs in solving complicated optimization issues in machine learning, image analytics, and robotics. The overall contribution of the study is the synthesis of all the diversity of GA implementations with the focus on their efficiency in big, chaotic search spaces. It is however purely conceptual and thus not experimentally verified meaning that it is a bit less applicable. Notwithstanding this shortcoming, it offers a sound theoretical foundation based on which the mechanisms of GA are to be studied and implemented in the intelligent system making it optimize functions.

The third article by Tomforde (2023) examines the role of GAs to improve innovation and efficiency in the optimization of technologies. The paper underlines the role of natural evolution imitation by GAs to cope with more complex problem-solving task in fields of software engineering, robotics and electronic circuit design. When talking about the essential issues such as computational intensity and parameter tuning, Tomforde points out the benefits of GAs in obtaining optimal solutions. Although the research does not present quantitative data and empirical findings, it provides a worthwhile conceptual understanding on how GA frameworks spur innovation and nimbleness in the intelligent technology design approach. It adds value to other papers in that it fills the gap between theoretical knowledge and cross-domain utility by highlighting GAs as central instruments of technological change and streamlining.

fourth study is Hassan et al (2025). concerned with scheduling the tasks in multiprocessor real-time systems with the use of a new GA based method. The algorithm was compared to three classical scheduling methods which included Evolutionary Fuzzy-Based Scheduling, Least Laxity First and Earliest Deadline First. The proposed GA had always recorded zero missed deadlines, lower average response time and showed high reliability during heavy system loads. Its non-preemptive and independent task design was effective in enhancing the efficiency in the whole system. One of the merits of this study is its high level of empirical rigor and comparative benchmarking. But it also assumes the same processors which restricts its ability to be adaptable to heterogeneous environments. Nevertheless, the research also provides strong empirical data that GAs may help a lot to improve the scheduling and optimization of the performance of real-time systems.

The fifth article written by Chen & Hu (2022) explores the use of an adaptive enhanced genetic algorithm in intelligent control systems in agricultural greenhouses. The study aims at optimization of the multi-energy supply system to ensure that there are no fluctuations with changes in environment that results in temperature variation below 0.5 C and humidity variation below 1 percent RH. The dynamism aspect of the algorithm allowed it to adapt to changes in the

environment dynamically, which proved its efficiency by being tested in real-life and not on a computer. This adaptive GA design and practical validation combination highlights the ability of the algorithm to work with non-linear and multi-variable systems. This study has the limitation of being domain specific to agricultural systems but it has, on the other hand, proven the usefulness of GA optimization outside of computational settings into physical resource-driven intelligent control systems.

Lastly, Sun & Sun (2025) published by IEEE identify a hybrid optimization model which combines genetic algorithms with artificial intelligence methods, i.e. convolutional neural networks (CNNs), to optimize product design processes. The hybrid solution offered 30 percent improved convergence rate, 25 percent greater design efficiency, cost reduction of 20 percent and 15 percent time to market. In case studies that were conducted in the automotive and consumer electronics industries, there was a notable increase in efficiency, durability and environmental sustainability. This combination of GA and AI was more successful in creating an exploration-exploitation balance that allows more adaptive optimization. But this is expensive in terms of computation, and is not very scalable in resource-constrained environments. Nevertheless, it is the future perspective of optimization studies in that it involves a combination of the evolutionary computation with the intelligent learning methods to effectively deal with high-dimensional multi-objective problems.

Synthesis of Findings

These six papers demonstrate the flexibility and strength of genetic algorithms in improving the functionality of intelligent systems in various areas of intelligent systems including robotics, real time computing, agriculture and design engineering. All the researches also seem to concur that optimization with the help of GA improves efficiency, flexibility, and system intelligence since the complex problems that are out of reach of conventional methods can be solved. Conceptual frameworks are set using theoretical literature by Naaman et al. (2025) and Tomforde (2023), whereas applied research by Chabane and Guenounou (2025), Hassan et al. (2025), Chen & Hu (2022), and Sun & Sun (2025) empirically validates this concept and innovates the hybrid model. The combination of GAs and AI that Sun and Sun showed can be seen as a paradigm shift towards more intelligent, self-optimizing systems. Despite the present difficulties in computational cost, domain applicability and real-world scalability, all these studies stand in agreement that genetic algorithm optimization is a paradigm shifting technology that would help in improving the efficiency, intelligence and strength of the current computational systems.

Summary Table

Paper	Year	Authors	Methodology	Key Findings	Limitations
1	2025	Chabane & Guenounou	Two-phase enhanced GA	Improved task allocation and 90% faster computation	Simulation-based; lacks real implementation
2	2025	Naaman, Ahmed & Mahmood	Literature review	GA universality and adaptability	No experimental data
3	2023	Tomforde	Conceptual review	GA enhances innovation in technology optimization	Lacks quantitative validation
4	2025	Hassan, Ibrahiem & Madian	GA-based scheduling algorithm	High reliability; zero missed deadlines	Limited to identical processors
5	2022	Chen & Hu	Adaptive improved GA	Stable real-world control performance	Narrow domain (agriculture)
6	2025	Sun & Sun	Hybrid GA + CNN (AI)	30% faster convergence, 25% improved efficiency	High computational cost

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