

DEVELOPMENT AND EVALUATION OF HIGH PERFORMANCE HYBRID OPTIMIZATION MECHANISM FOR MICROSTRIP ANTENNA DESIGN CONFIGURATION

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Received: August 03, 2023; Revised: February 04, 2024; Accepted: March 01, 2024

Abstract

An efficient and high degree of resolution must be achieved by integrating optimization solutions into the design of high-performance antennas, which has become a prominent consideration in recent years. To achieve the best results when making decisions, optimization procedures like particle swarm optimization (PSO), ant colony optimization (ACO), and mean variance optimization (MVO) have been widely used. However, these optimization algorithms have a number of drawbacks. For example, the ACO-based solution does not support application complexity, while PSO exhibits a low rate of convergence throughout the course of the process cycles. In this work, a hybrid approach for the design of microstrip antennas has been suggested by integrating PSO and MVO techniques, which greatly improves the outcomes, taking into account the limits of existing optimization processes. The proposed hybrid approach is capable of combining the PSO-MVO with multiple parameters like iteration, upper bond, lower bond, and objective function. Finally, research work evaluates the time consumption and error rate with respect to conventional techniques. Results show an improvement of 61% and 50% in the time consumed by the hybrid PSO-MVO approach as compared to the PSO and MVO approach respectively. The hybrid PSO-MVO achieves an accuracy of 87.15 which is 3% better than individual optimization techniques. Simulation work has been made in a Matlab environment in order to get the best solution using a hybrid optimization technique.

Keywords: ACO; Antenna design; microstrip antenna; MVO; optimization; performance; PSO

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Introduction

A primary goal of Antenna is to enhance the emotional connection between users and their surroundings. When operating UAVs over great distances or in areas with limited visibility, antenna design becomes more crucial. Moreover, during the design of wireless device, it is crucial to consider the optimal operating distance and how far the antenna must travel to transmit the signal. For a given packet error rate (PER) and receiver sensitivity, the more the radio's broadcast power, the farther the signal will go. Equally, a receiver radio configured to operate with minimum radiation incident at the antenna may do so. To make sure that the radio's power is effectively sent to the antenna, the RF architecture and radio matching network must be well-designed. Ghaffar *et al.* (2020) presented a compact tri-band ultra-wideband antenna using a partial ground plane. The designed antenna's frequency range is varied between 3.1 GHz and 10.6 GHz. The proposed antenna takes inspiration from the classic rectangular patch antenna, but its working bandwidth is increased thanks to the inclusion of slots, stubs, and a flawed ground construction. The return loss results for all resonant frequencies and the single wideband are encouraging. To further show the proposed antenna's viability for future Ultra-wideband (UWB) and multiband portable devices, it has been compared to previous studies in the literature. Multiband microstrip antenna for usage in fractal and faulty ground structure wireless communication systems, as described in this abstract by Amandeep Kaur and Malik (2021). A prototype antenna is constructed on a double-layer Printed Circuit Board (PCB) made from Rogers RT Duroid 5880 dielectric material having dielectric constant of 2.2. This microstrip patch antenna is redesigned in elliptical shape fractal geometry that allows further miniaturization. Furthermore, adopting defect-containing ground structures allows for both high gain and bandwidth in the impedance domain. Electromagnetic energy is connected to the radiator through a small microstrip feedline that enters via a lumped port. The suggested antenna can operate across a large frequency range and experimental validation is used to confirm results from computer simulations. Antennas operating in the ISM (Industrial Scientific and Medical) band are used by a wide variety of wireless technologies, including Wireless Local Area Network (WLAN) (2.4/5.2/5.8 GHz) and Wi-Fi (2.4 GHz). Not only are the S-band (2.5-5.0 GHz) and X-band (8-12 GHz) frequency ranges covered, but so are their respective communication subsets (2.3-2.4 GHz). The work of

Tiwari and Malik (2020) compares the gain, performance, and design principles of a number of antennas. It was explored how ultra-wide-band (UWB) antennas may be used in future 5G mobile networks. The designed antennas are speculated to be planar in geometry, with a purposefully small size, in order to achieve best performance within the wide frequency range needed in the 5G potential frequency range. A wide variety of antenna layouts are already available that can provide the high transmission rates needed by UWB systems. One of the antennas in the receiver is designed specifically for ultra-wideband (UWB) reception; this antenna is termed a Vivaldi antenna. Due to its directional radiation design, it cannot be used with devices that provide quick and easy communication between transmitters and receivers over long distances, such as mobile phones and other hand-held electronics. Mono-cone and bi-tapered receiving devices are so enormous that they are likely used alone. Two UWB receiving devices in the frequency range of 3.1GHz-10.6 GHz are the log intermittent antenna and the winding radio wire, both of which find usage in indoor long-distance communication applications or as devices that are both adaptable and small. This is because of the massive physical sizes of these objects and the high frequency and very loud ringing effect caused by their dispersive qualities. This study examines all of the existing conventional and hybrid antennas to identify the characteristics that will be most helpful in developing a high-gain, high-performance ultra-wideband (UWB) antenna for %G. For use in 5G networks, UWB antennas have shown to have the requisite dynamic characteristics. Because of this, the typical isolation issues that arise at very low temperatures may be avoided and hence it is easy to use since it creates a hard copy within the phone. A tiny, planar, coplanar waveguide (CPW)-fed microstrip patch antenna was investigated by Gupta *et al.* (2021) and it showed a 10 dB impedance bandwidth from 2.59 and 7.61 GHz. The suggested antenna's ultimate form is arrived at by a parametric study of several design elements. VSWR, return loss, radiation sensitivity, and gain are only some of the metrics that are measured on the prototype in the lab. Findings from simulation are in agreement with experimental data. The proposed antenna has dimensions of 0.61 mm 0.44 mm 0.027 mm and an impedance bandwidth of 5.02 GHz (10 dB). This means it has potential for usage in a wide variety of wireless contexts, including but not limited to WLANs, Worldwide Interoperability for Microwave Access (WiMAX), fixed satellite

services, P2P networks, etc. Meta-materials were used in the development of a high-performance, wide-bandwidth, rectangular patch antenna by Colaco and Lohani (2021). The proposed device's Rogers RT/Duroid substrate contributes to its low dielectric constant of 2.2 and its low dielectric loss tangent of 0.0010. This configuration allows for the attainment of the 26 GHz resonant frequency. The simulations performed by the FEKO program have been assessed for their efficacy.

Rectangular microstrip patch antenna design and performance study was the focus of Elijah and Mokayef (2020). The antenna used in this research is well-suited for IoT applications because to its wide resonant frequency range (100 MHz to 5.8 GHz). The antenna's base was built using a FR-4 substrate. Here, CST software is used to model this process (version 2014). Within the scope of this research, both traditional microstrip antennas and enhanced microstrip antennas with a U-shaped design were developed. Both of these antennas were evaluated for their gain, bandwidth and return loss. The key takeaways from this research were that the designed U-shaped antenna had better bandwidth in the range of 135 MHz to 168 MHz, gain (2 dB to 4 dB), and return loss of 0 dB than a regular antenna (down from -20 dB). The upgraded antenna is also capable of operating at a frequency of 5.755 GHz, making it a good choice for IoT applications. With the use of analysis, mathematical calculations, and computer-aided techniques, such those described by Kumar *et al.* (2022), designers might potentially make antennas with better transmission quality. The most optimal results may be achieved by integrating Machine Learning and Deep Learning into the design phase. The optimization process, in particular, is simplified. Optimization algorithms like genetic, particle swarm, evolutionary, etc., fall within the broad categories of local and global optimization techniques that may be used to achieve this objective. Several of the most widely used optimization techniques are introduced at a high level in this work. Few of the basics of patch antennas were presented by El Alami *et al.* (2013) and the purpose of this WIMAX application is to optimize the size of the patch antenna such that its resonance frequency is 3.55 GHz. Miniaturized microstrip patch antennas (MPAs) may be made more efficient by coating them with a thin layer of a high relative permittivity material, as proposed by Boudjerda *et al.* (2022). By utilizing a thin layer, the antenna's resonance frequency may be decreased without altering the antenna's patch size. Through the application of genetic algorithms, the size of the patch is optimized to maximize the antenna's performance while maintaining a minimal profile. With the help of thin film,

the resonant frequency was decreased from 5.8 GHz to 4.0 GHz and its footprint was reduced by about 60% in comparison to a conventional antenna. The suggested antenna improved in voltage standing wave ratio (VSWR), bandwidth, and return loss.

Improved versions of the method, dubbed IWOA, were proposed by Fan *et al.* (2021) and in this work, a number of innovative ideas, such as adaptive weight, nonlinear control parameter, and Cauchy disturbance, are adopted before the efficiency of the method may be improved. Antenna designs may be automatically simulated using HFSS and MATLAB. Using a trustworthy conductor patch material and as few dimensions as possible, Saman Ezzulddin *et al.* (2022) designed a single, 28 GHz, rectangular microstrip patch antenna (RMPA). Because of this, a CST-based microwave studio has been built up to scrutinize the layout of a single patch (RMPA). Due to its (0.2) mm thickness, (2.2) relative permittivity, and (0.035) loss tangent, the (RT) Duroid-5880 is employed as the dielectric material throughout all stages of the modelling process. The results of the optimization show that the best radiation performance from the RMPA antenna may be achieved with a Copper patch measuring (7.2) mm³. Two more approaches were proposed for improving the design of microstrip antennas by Fan *et al.* (2018). One such method is the Gaussian Process Particle Swarm Optimization (GP-PSO) methodology, where a Gaussian Process model stands in electromagnetic simulation software and a Particle Swarm Optimization (PSO) algorithm is used to get the optimum results. This method enhances a dual-mode MSA that uses GPS and Beidou satellites. Results show the designed antenna not only delivers on its promised performance, but also significantly reduces optimization time. In the second method, the fitness-estimation-based PSO (FE-PSO) algorithm is utilized to enhance the computing efficiency of the GP-PSO algorithm. In the third iteration of the proposed FE-PSO algorithm, based on the explicit evolution formula of PSO, it is possible to forecast the fitness value of particles using a newly constructed formula. To save time, the GP-PSO technique foregoes the usage of a GP model in favor of a formula that yields a prediction result. With this method, a Yagi MSA can function at its absolute best. The results demonstrate that rapid optimization may be achieved provided the design validity is ensured.

Artificial neural networks, namely a method developed by Fei-Yan *et al.* (2016) that makes use of the support vector machine (SVM) and a hybrid kernel function (HKF) to accurately estimate the resonance frequency of a tiny microstrip antenna (MSA), were suggested (HKF). We may adjust

the SVM parameters and the HKF weight coefficients with the help of a particle swarm optimization strategy. Alternatives to standard KF include polynomial KF (a special case of global KF) and Cauchy KF (a special case of local KF). The proposed procedure has been tested, and shown to be accurate, in the UCI database. According to the results of the evaluation, the SVM's ability to learn and generalize may be improved by using the HKF. Additionally, an inverted F-shaped antenna and an L-shaped MSA's resonant frequencies may be predicted using the proposed method. Combining the particle swarm optimization-based SVM with the HKF increases forecasting accuracy, demonstrating the method's viability even for small data sets. An improved version of the Particle Swarm Optimization (PSO) method was presented by Zhao *et al.* (2021), which produces higher quality outcomes in less time. Interval prediction is utilized by optimization to aggregate several metrics into a single fitness value, which in turn is used to steer the optimization in the desired direction. As a way to verify the validity of the proposed optimization, we use the improved PSO method to simultaneously optimize the S 11 and bandwidth of a regular patch Yagi antenna. The findings show an 80% reduction in optimization time compared to traditional PSO. One branch of AI is called "Swarm Intelligence," and it was inspired by the intelligent collective behavior of social swarms, first described by Gad (2022). In this study, the Systematic Review (SR) technique is used to survey the present status of the field and active areas of investigation from many different vantage points, including algorithmic strategies, varied application domains, pressing problems, and promising future directions. This research employs a technical taxonomy of the chosen literature to investigate PSO hybridization, improvement, and modifications, as well as practical applications of the algorithm in the sectors of medical, ecology, industry, commerce, smart cities, and more. Several technical parameters must be taken into consideration while comparing the effectiveness of different PSO methods and software packages. Every reviewed study has both beneficial advantages and unavoidable problems, and they are explained together with the clues that have been made to cope with the limitations of those studies, while also highlighting the outstanding challenges and future research opportunities around the algorithm. In Nguyen *et al.* (2022), detail the creation of a miniature giraffe-shaped ultra-wideband (UWB) patch antenna. The microstrip antenna has a rectangular shape that is divided up into numerous smaller squares, or "pixels." Binary values of 1 or 0 are assigned to these pixels based on

the fitness function used by the algorithm. By eliminating the pixels with value 0, the HFSS platform optimizes the antenna to reach ultra-wideband performance in only three iterations.

The effectiveness of power allocation in MIMO radar with widespread antennas for target tracking was studied by Darzikolaei *et al.* (2022). To achieve this, first Several Input Multiple Output (MIMO) radars with multiple, independently steered antennas is set up, and then a model of the target's motion is developed using the constant velocity (CV) technique. Next, we determine how confident we can be in our current values for the goal parameters (the combined target location and velocity). In a problem involving the allocation of power, this serves as the criteria. When a complex Gaussian model is used to estimate the target's radar cross-section, this function becomes more complex (RCS). Because the objective function is nonlinear, the proposed power allocation problem is nonconvex. As a result of this issue, a method for power distribution based on particle swarm optimization (PSO) is created. Multiple criteria, such as the total number of antennas and the many possible antenna configurations, are put through virtual trials to determine the efficacy of the proposed strategy. The results validate the usefulness of the proposed strategy. A MIMO radar system's antenna may be spaced widely apart, providing several views of the target. In this kind of radar system, all received signals are sent to a single computer. In military actions, the distribution of power is essential. This makes it an important factor to think about while devising solutions for the target tracking problems encountered by MIMO radar. Power allocation minimizes tracking errors by determining the most efficient method for allocating power to transmit antennas, given the available transmit power. Based on their research into the problems with MVO and possible solutions, Guerard *et al.*, (2012) created a factor-based portfolio optimizer. There are further factors to consider, such as size, Value premium, income and yield, momentum, and volatility. The importance of momentum in portfolio construction in the context of the Indian capital markets will be emphasized. Investors are reevaluating some of the fundamentals of their trade in light of the dynamic nature of capital markets. Conventional Mean Variance Optimization (MVO) and its subsequent updates have been called into question. The importance of investor behavior in shaping a portfolio has been increasingly acknowledged in recent years. Decision-making problems were among those studied by Tung *et al.* (2019) that employ the concept of swarm intelligence (SI). The Ant Colony Optimization (ACO) approach takes its influences from SI

algorithms and uses a swarm of agents that work locally and follow a few basic rules to get a global optimum outcome. The ACO variation is employed in the design of the microstrip patch antenna for its practicality. The experimental antenna has a bandwidth of 50 MHz to 170 MHz and is designed to operate in the 3.5 GHz frequency range (Kumar *et al.*, 2022; Guttula *et al.*, 2023). The abbreviations used in the paper are enlisted in Table 1.

Problem Statement

The research paper explains various optimization techniques that have been utilized for optimizing antenna design. It has been observed that existing optimization mechanisms have their own limitations. The ACO based approach does not support Application Complexity whereas Neuro Fuzzy based module is enabled to provide reliability in antenna design. ACO based module can be used only to compute the length of shortest path. But PSO with MVO provides the best solution in a small time. So, it has become essential to propose an optimized antenna configuration module which can resolve the existing issues in this field. Moreover it has been observed that MVO based PSO is performing fast as compared to other optimization techniques. Time taken and accuracy of solution, need to be considered in order to perform comparative analysis of these optimization techniques. Figure 1 shows the structure of Micro-strip patch antenna for optimization design. The proposed work focuses on assessing the compatibility of design specifications with optimized antenna parameters. This involves defining an objective function encompassing goals like maximum gain, desired radiation pattern, and required bandwidth. Fitness evaluation determines the design's fitness using the established objective function, calculating values for antenna parameters derived from optimization algorithms. Constraints account for size restrictions and material properties. Convergence analysis monitors the algorithms' convergence.

Proposed Work

The proposed hybrid approach of optimization for micro-strip antenna is capable to integrate the PSO-MVO with multiple parameters like iteration, upper bond, lower bond and objective function. Finally, research work is calculating the time consumption and error rate with respect to conventional techniques. Figure 2 shows the adopted research methodology. That shows flow of

Table 1. Various Abbreviations

S. No.	Abbreviation	Full name
1	PSO	particle swarm optimization
2	ACO	ant colony optimization
3	MVO	mean variance optimization
4	PER	packet error rate
5	UAV	unmanned aerial vehicle
6	UWB	Ultra-wideband
7	PCB	Printed Circuit Board
8	WLAN	Wireless Local Area Network
9	CPW	coplanar waveguide
10	VSWR	Voltage standing wave ratio
11	WiMAX	Worldwide Interoperability for Microwave Access
12	MPAs	microstrip patch antennas
13	GP-PSO	Gaussian Process Particle Swarm Optimization
14	SVM	support vector machine
15	HKF	hybrid kernel function
16	MSA	microstrip antenna
17	MIMO	Several Input Multiple Output

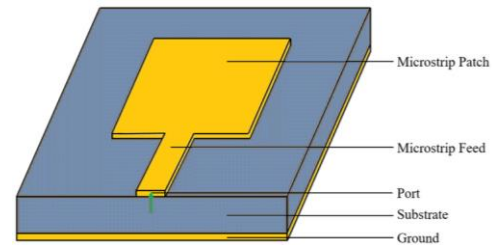


Figure 1. Designed structure of Micro-strip patch antenna

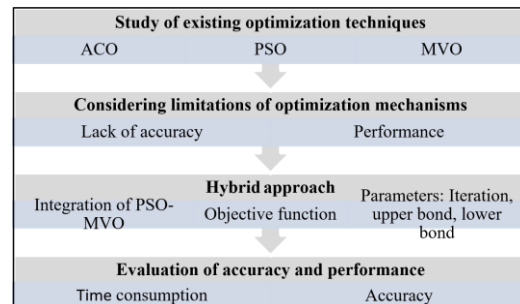


Figure 2. Research Methodology

the work accomplished starting from study of the existing optimization techniques PSO, ACO, and MVO then finding their limitations in terms of accuracy and performance. Finally, the novel approach of the optimization is developed with the integration of the PSO and MVO optimization approaches and then its performance parameters are evaluated and compared with the existing approaches. In the proposed hybrid approach, the number of iterations represents the number of times the optimization algorithm goes through the entire

population. A higher number of iterations may allow the algorithm more chances to explore and converge to an optimal solution. Setting appropriate upper and lower bounds which represent allowable design parameters like dimension and material property of the micro-strip antenna ensures that the optimized solution remains within physically realistic and feasible limits. The objective function quantifies the performance of the microstrip antenna based on design goals. It could involve parameters like gain, bandwidth, or return loss. The hybrid approach aims to optimize this objective function by adjusting the antenna parameters. Time Consumption refers to the computational time required for the optimization algorithm to converge to a solution. The hybrid approach is evaluated not only based on the quality of the optimized solution but also on how efficiently it arrives at that solution. And finally, the error rate is a measure of how far the obtained solution is from the ideal or target solution. It could be defined based on the difference between the optimized and desired values of the objective function or other performance metrics. Lower error rates indicate a more accurate optimization process.

Hybrid Multiverse Optimization (PSO-MVO) Derivation

The base expression for Multiverse Optimization (MVO) is given by Equation (1) of Particle Swarm Optimization (PSO) is presented whose basic mechanism is influenced by social expression of fishes. PSO consists of P_{best} , and G_{best} . Using these arithmetic equations not only locations are refreshed, but speeds are also revised with change of direction

$$v_{ij}^{t+1} = wv_{ij}^t + C_1R_1(P_{best}^t - X^t) + C_2R_2(G_{best}^t - X^t) \quad (1)$$

Here

v_{ij}^{t+1} = velocity of i^{th} particle at $(t+1)$ time
 w = rage of inertia factor from (0.4 to 1.4)
 wv_{ij}^t = present motion
 X^t = state of the particle at time t
 P_{best}^t = bestpersonal at time t
 C_1 = range of the self confidence varying from 1.5 to 2
 R_1 = 1st random number
 $R_1(P_{best}^t - X^t)$ = memory influence of the particle
 C_2 = range of the swarm confidence varying from 2 to 2.5
 R_2 = 2nd random number
 G_{best}^t = global best at time t

$R_2(G_{best}^t - X^t)$ = swarm influence

$$X^{t+1} = x^t + v^{t+1} (i = 1, 2..NP) \text{ And } (j = 1, 2..NG) \quad (2)$$

Here

X^{t+1} = state of the particle at time $t+1$

Where

$$W = w^{\max} - \frac{(w^{\max} - w^{\min}) * \text{iteration}}{\text{maxiteration}} \quad (3)$$

$w^{\max} = 0.4$

$w^{\min} = 0.9.v_{ij}^t, v_{ij}^{t+1}$ Considered as velocity of j^{th} member of i^{th} particle in iteration of (t) and $(t + 1)$.

The algorithm of Multi-verse optimizer equation (MVO) takes its inspiration from the alphabets black hole, white hole, and wormhole. These alphabets are all written in an arithmetical format. The thought to have a significant section in the creation of the planet is assumed as white hole. The spectacular gravitational effect of black holes attracts everyone's attention. Wormholes function as time and space travel conduits. It is feasible to transport things across the globe at a very fast speed in this way. The steps outlined below are used in the development of MVO:

- The high inflation level shows greater chances of white hole presence.
- The low inflation shows lower chances of black hole presence.
- Populations which maintain level of inflation high, transmit substances by means of white holes.
- Population which does not maintain high level of inflation accepts additional substances by means of black holes.

Each element of this universe tries to move forward in support of population which is fit. It has been done by worm holes. For this, level of inflation is not taking in to account. Each and every element takes a movement in the direction of population where the speed of spread is less from a universe whose rate of spread is high. It becomes responsible for the growth of average spreading speed of complete cosmoses in the company of transition. As rapidly a change occurs, population is organized depending upon the speed of spread. After that it chooses one from them. For this purpose, roulette wheel is bringing in to use in terms of a white hole. Next stages are employed in support of this method.

Derived Hybrid PSO-MVO Expression

The integration of PSO and MVO equation give the equation of Hybrid PSO-MVO where the best strength of PSO and MVO are merged together towards optimum solution for the target. In this method the MVO Universe value is replaced by Pbest value of the PSO. The derived hybrid expression is given in Equation (4). The first term of the Equation (4) wv_{ij}^t represents the inertia or the tendency of a particle to maintain its current velocity. The second term $(C_1 R_1 (Universes^t - X^t))$ is similar to the cognitive component of the PSO algorithm. It adjusts the velocity based on the difference between the current position of the particle (X^t) and a randomly selected solution from the population ($Universes^t$). Whereas, the third term $(C_2 R_2 (Gbest^t - X^t))$ is similar to the social component of the PSO algorithm. It adjusts the velocity based on the difference between the current position of the particle (X^t) and the global best position ($Gbest^t$).

$$v_{ij}^{t+1} = wv_{ij}^t + C_1 R_1 (Universes^t - X^t) + C_2 R_2 (Gbest^t - X^t) \quad (4)$$

In the given expression v_{ij}^{t+1} represents updated velocity of the i^{th} particle in the j^{th} dimension at $(t+1)^{th}$ iteration, w represents inertia weight which controls the velocity of previous particle. v_{ij}^t represents the current velocity of the i^{th} particle in the j^{th} dimension. The acceleration coefficients are denoted by C_1 and C_2 which control the influence of personal best (Pbest) and global best (Gbest) information on the particle's velocity update. The term R_1 and R_2 represents random values between 0 and 1, generated independently for each dimension and particle at every iteration.

Universes^t In the context of MVO, "Universes^t" typically represents the solutions in the search space. In this hybrid algorithm, the Universes^t term is replaced by X^t , which denotes the current position of the particles in the search space at the t^{th} iteration. Whereas the term $Gbest^t$ denotes the global best position found by any particle in the population up to the t^{th} iteration. By combining elements from PSO and MVO, this hybrid algorithm aims to benefit from the exploration capability of PSO and the exploitation capability of MVO, with the replacement of the MVO's universe value by the PSO's personal best value.

Result and Discussion

In the simulation, 6 configurations of rectangular patch microstrip antenna have been considered and designed. The dynamic range of notch length and width are varied for different design specifications and then PSO, ACO, MVO and Hybrid PSO-MVO techniques are adopted to find the best solution. Simulation work considered optimization techniques PSO, ACO, MVO to get best solution. Time consumption of hybrid PSO-MVO approach has been compared to PSO, ACO, and MVO mechanism. Results conclude that the time consumed in hybrid PSO-MVO is less as compared to conventional optimization mechanisms. Table 2 is showing time consumption comparison while Table 3 is showing accuracy comparison. Figure 3(a) compares the time consumed in making the decision of the optimization using PSO, ACO, and MVO. Here it can be seen that for every design PSO is taking more time in taking the decision of the optimization than ACO and MVO whereas MVO takes comparatively least time in making

Table 2. Consumed time

Design no.	PSO	ACO	MVO	HYBRID PSO-MVO
1	1.44960657	0.92136785	1.14737632	0.56814772
2	2.34645343	2.24699631	1.44001731	0.79825621
3	3.68178718	3.13416548	3.26963741	2.28482197
4	4.79014995	4.71202842	4.11676215	3.57447614
5	5.81472532	4.88028459	5.01495496	4.34306821
6	6.26949593	5.83295329	5.43516345	4.48310777

Table 3. Accuracy value

Design	PSO	ACO	MVO	HYBRID PSO-MVO
1	85.08626614	85.40466035	86.14863604	87.14513083
2	85.1988887	86.136927	86.26041092	86.84848307
3	85.36635171	86.19011686	86.90544804	86.95146504
4	85.53135651	86.0963886	86.86008803	87.71733901
5	85.30672787	85.34538433	86.31682985	86.57964443
6	85.45962757	86.01528894	86.74215926	87.41806379

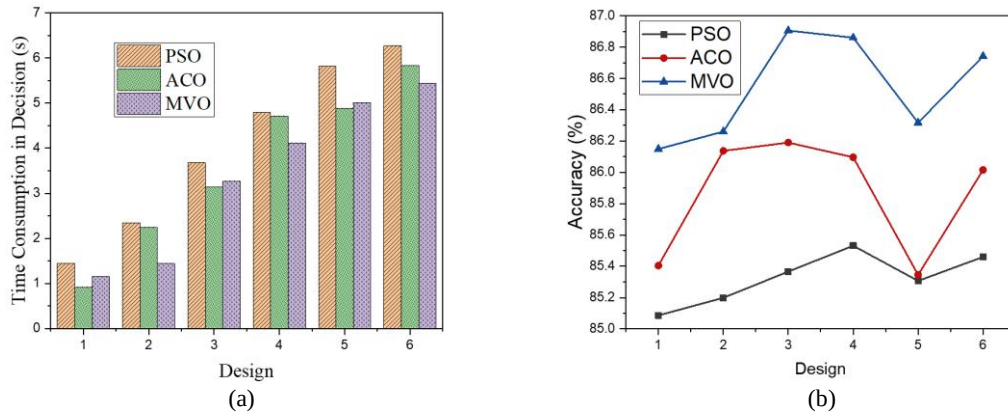


Figure 3. Comparison of (a) Consumed time and Accuracy (%) in decision making between PSO, ACO and MVO

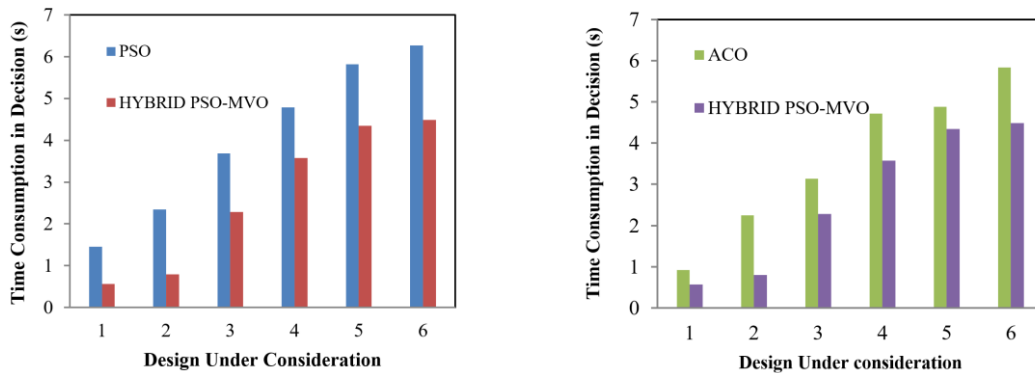


Figure 4. Comparison of time consumption in taking decision between PSO and Proposed methodology

Figure 5. Comparison of time consumption in taking decision between ACO and Proposed methodology

the decision. Figure 3(b) compares the accuracy results in taking the decision by PSO, ACO, and MVO mechanism and it can be noticed from the Figure 3(b) that MVO shows the highest accuracy while PSO shows lowest accuracy among the three.

It can be seen from the Figure 4 that the PSO techniques takes more time as compared to the proposed hybrid methodology in taking the decision of the optimized design. There are six designs are considered for this evaluation and individually PSO and Hybrid methodology is applied to each design and the time requirement is plotted in Figure 4. PSO takes 6.269 sec while proposed methodology takes only 4.4 sec for sixth design.

The Comparison of time consumption in taking decision between ACO and Proposed methodology for the optimization is shown in Figure 5. It can be seen from the Figure 5 that the ACO techniques consumes more time as compared to the proposed hybrid methodology in taking the decision of the optimized design. ACO

takes 5.8 sec while proposed methodology takes only 4.4 sec for sixth design.

The Comparison of time consumption in taking decision between MVO and proposed methodology for the optimization is shown in Figure 6. It can be seen from the Figure 6 that the ACO techniques consumes more time as compared to the proposed hybrid methodology in taking the decision of the optimized design. ACO takes 5.5 sec while proposed methodology takes only 4.4 sec for sixth design.

The Time consumption for all the techniques is collectively plotted in Figure 7. It can be seen from the Figure 5 that the proposed hybrid methodology in taking the decision of the optimized design consumes smallest time as compared to the all other techniques. Results shows an improvement of 61% and 50% in the time consumed by hybrid PSO-MVO approach as compared to PSO and MVO approach respectively.

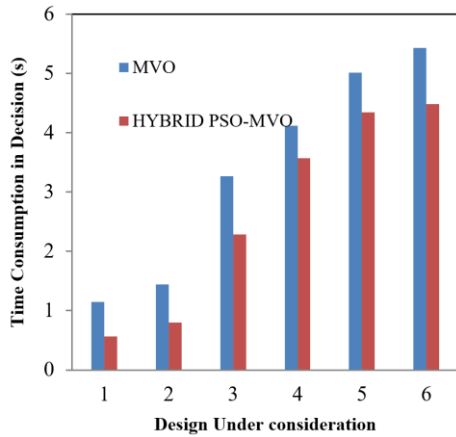


Figure 6. Comparison of time consumption in taking decision between MVO and Proposed methodology

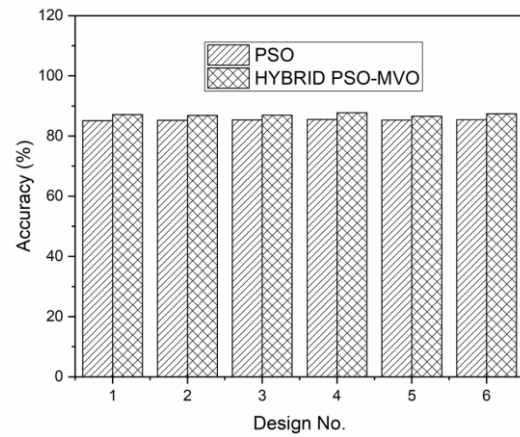


Figure 8. Comparison of Accuracy variations between PSO and Proposed Hybrid-MVO methodology

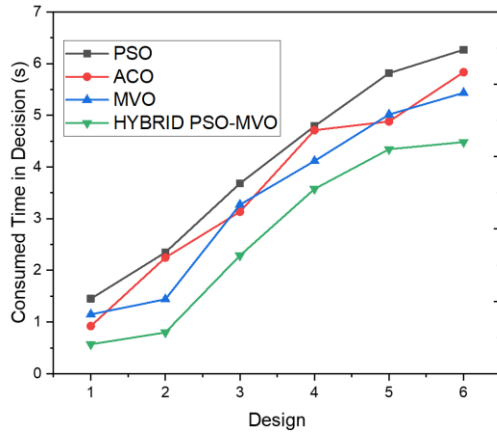


Figure 7. Performance variations of PSO, ACO, MVO, and Hybrid PSO-MVO

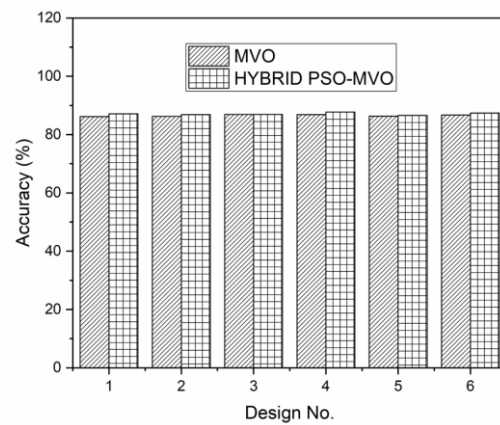


Figure 9. Comparison of Accuracy variations between MVO and Proposed Hybrid PSO-MVO methodology

In microstrip antenna design, the accuracy values of the solution while making the decision listed in Table 3 (in revised manuscript) are evaluated considering various performance metrics. Keeping the primary aim to evaluate how well the design specifications meet the optimized parameters of the antenna, the steps like defining objective function, fitness evaluation, constraints, and conversion analysis are performed to evaluate the accuracy. The objective function covers the design goal such as maximum gain, desired radiation pattern, and required bandwidth. Fitness evaluation calculates the fitness of the antenna design by already defined objective function. This includes calculating the objective function value for each design of antenna parameters obtained from the optimization algorithms. The size restriction and material properties are considered by

constraints. Finally, the convergences of the algorithms are monitored by convergence analysis. The Comparison of accuracy in taking decision between PSO and Proposed methodology of Hybrid PSO-MVO for the optimization of microstrip antenna design is shown in Figure 8. It can be seen from the Figure 8 that the PSO techniques has low accuracy as compared to the proposed hybrid methodology in taking the decision of the optimized microstrip antenna design. PSO has 85% accuracy while proposed methodology has an improvement and shows 87% accuracy in the optimization of the microstrip antenna design.

Figure 9 shows the comparison of accuracy in taking decision between PSO and Proposed methodology of Hybrid PSO-MVO for the optimization of microstrip antenna design. It can be seen from the Figure 9 that the MVO techniques

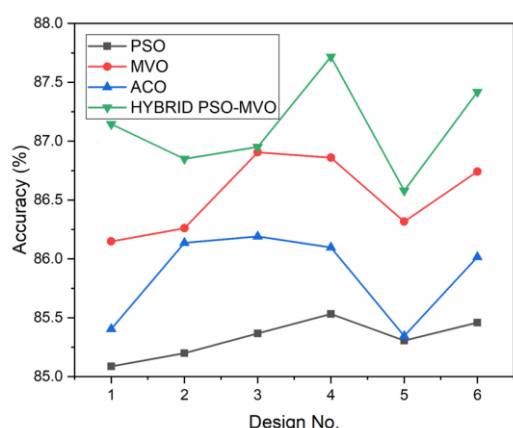


Figure 10. Variation of accuracy in various methods

has low accuracy as compared to the proposed hybrid methodology in taking the decision of the optimized microstrip antenna design. MVO has 85.5% accuracy while proposed methodology has an improvement and shows 87% accuracy in the optimization of the microstrip antenna design.

The accuracy for all the techniques is collectively plotted in Figure 10. It can be seen from the Figure 10 that the proposed hybrid methodology shows higher accuracy among the other optimization techniques in taking the decision of the optimized microstrip antenna design. The hybrid PSO-MVO achieves an accuracy of 87.15 which is 3% better than individual optimization techniques.

Conclusion and Future Scope of Research

In this manuscript, the novel hybrid PSO-MVO approach of the micro-strip antenna design optimization is developed with the integration of the PSO and MVO optimization approaches and then its performance parameters are evaluated and compared with the existing individual PSO, ACO, and MVO approaches. Simulation concludes that the proposed hybrid approach is performing better than conventional ACO, PSO, and MVO approaches. Results shows that the proposed approach provides better accuracy during decision making regarding micro strip antenna configuration and consumes less time as compare to the existing approaches. Thus the hybrid approach has provided the benefit of accuracy and performance for antenna design. To verify the accuracy and time consumption while optimization, six design samples are considered and then the developed algorithm is implemented to evaluate the performance parameters. It is seen that accuracy is improved in the range of 2.5% to 4% with existing PSO and

MVO optimization techniques whereas the developed optimization techniques consume 50 % to 70% less time in decision making. Resource scheduling optimization's scope is the technique through which inputs like resource needs, available resources, and scheduled use are defined.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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