Chapter

A Survey on Recent Trends of PIO and Its Variants Applied for Motion Planning of Dynamic Agents

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Abstract

Pigeon Inspired Optimization (PIO) algorithm is gaining popularity since its development due to faster convergence ability with great efficiencies when compared with other bio-inspired algorithms. The navigation capability of homing pigeons has been precisely used in Pigeon Inspired Optimization algorithm and continuous advancement in existing algorithms is making it more suitable for complex optimization problems in various fields. The main theme of this survey paper is to introduce the basics of PIO along with technical advancements of PIO for the motion planning techniques of dynamic agents. The survey also comprises of findings and limitations of proposed work since its development to help the research scholar around the world for particular algorithm selection especially for motion planning. This survey might be extended up to application based in order to understand the importance of algorithm in future studies.

Keywords: Pigeon Inspired Optimization, Dynamic Agents, Optimization, Bio-Inspired Computation, Motion Planning Techniques

1. Introduction

The searching ability of homing pigeon is unmatched with other birds as it can be more accurate to achieve the destination despite long distance traveling [1]. Therefore homing pigeons have been widely used in 18th century to send and receive mails from far distances with minimal errors. As the telecommunication became popular for sending and receiving mails, the use of Pigeons almost vanished. With the advancement of technology, complex systems seek more accurate and stable algorithm to sort the convergence and stability issues.

The homing behavior of pigeons uses global searching ability to find the target with the help of natural navigation parameters i.e. Sun and Earth's magnetic field [2]. Initial studies on pigeons suggest that the pigeon can find the difficult destinations in most easy way when compared to other similar spices [3]. According to studies, the species appears to have a mechanism in which signals from magnetite particles are conveyed by the trigeminal nerve from the nose to the brain [4]. The capacity of pigeons to perceive varied magnetic fields was investigated, and it was discovered that the pigeons' amazing homing skills are nearly entirely reliant on small magnetic particles in their bills. Pigeons have iron crystals in their bills, which can give them a sense of direction [5, 6]. The flying direction of the moving bird is tuned by relative orientation mapped by two basic operators [7, 8]. **Figure 1** shows the basic approach used by the pigeons to map the route to destination and coming back to home [9].

Based on the searching ability for global search and route planning in pigeons encourage the researcher to introduce a novel optimization algorithm namely "Pigeon Inspired Optimization (PIO) algorithm" in 2014 for optimal solutions [10]. Further improvements in existing algorithm have been made time to time to concur variety of optimization problems including aerial field.

The unwanted uncertainties and complexities of various agents formed in a group still challenging for many researchers. To improve these hurdles proper motion planning of agents required that can reduce the convergence time and enhance stability of the system. The basic PIO has many improvements in its structure as well as combined with related algorithms in order to improve performance and stability of complex systems. This study sum up the motion planning techniques based on PIO and its variants of many agents including unmanned aerial vehicles (UAV's) with the help of findings and limitations. The works is based on open access PIO papers and its variants found on scholar portal of Google till May 2021.

Further layout of the chapter is as follows: Section 2 present novel idea in optimization problems. Section 3 discusses the mechanism and principle of PIO. Section 4 reviews the basic PIO and its variants applied on dynamic agents. Section 5 explains the conclusion and future work.

2. State of art

The state-of-the-art and intelligent optimizer has been introduce by Duan and Qiao and termed as Pigeon Inspired Optimization (PIO) Algorithm. This algorithm is based on homing behavior of pigeons that used simplified concept of route following either to detect target or coming back to home. The pigeons use earth

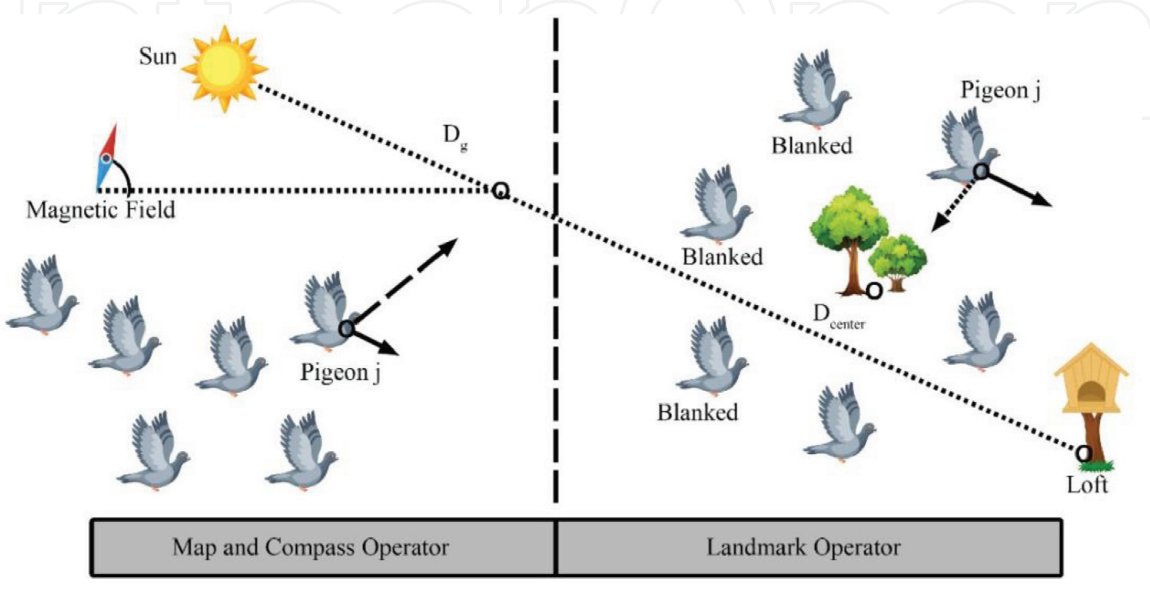

Figure 1.
Pigeon's homing behavior mechanism [9].

magnetic field, sun and landmarks for their complete journey as navigation tools. The basic PIO algorithm uses conventional mathematical expressions for "Map and Compass operator" and "Landmark operator" to produce navigation system.

Pigeons use magnetic based receiver to configure the map in their brains to perceive the earth field. To adjust the direction of their route they prefer the sun's elevation when available. They rely less on the sun and magnetic particles as they fly to their target. When the pigeons are getting close to their goal, they will rely on nearby landmarks. If they recognize landmarks then they can move fast and use direct route same as previous one. Now if any pigeon does not recognize landmark then they find one who is familiar with landmark and started following them.

3. Preliminaries of pigeon inspired optimization

3.1 Mechanism

In nature, homing pigeons use very simple navigation mechanism to find their homes. This mechanism is based on sunlight and pigeon's own shadow to trace out suitable route to destination. This mechanism is being very famous among active researcher around the globe. Moreover, this mechanism does not only depend upon the sun therefore other factor must be included to avoid errors in overcast condition or when the sun is not available.

Navigation mechanism of homing pigeon disturbed when the sun is hidden and unable to provide proper navigation the earth magnetic field becomes another navigation tool in order to maintain her flight. Since 2014, when this mechanism was first introduced by DUAN, researcher in the field validates that the magnetic field theory is being perfect tool for navigation.

3.2 Principle optimization

In Pigeon Inspired Optimization, a natural mechanism exists through which a pigeon can trace the path from initial point to the target. After years of studies it can be found that the pigeons are the most suitable bird for target detection, path planning and faster convergence related issues in optimization based problems [9, 10].

To obtain mathematical expression of PIO algorithm there are two separate operators i.e. the map & compass operator and the landmark operator; these operators describe the navigational effects of the sun and Earth's magnetic field, as well as that of familiar landmarks, respectively.

Suppose there is M pigeons are moving in the air space forming search space. When map and compass operator contain $Mc \leq Mc^1_{max}$, iteration for every pigeon's navigation j providing Mc^1_{max} is the maximum iteration and D_j^{Mc+1} is the position of pigeon j at iteration $Mc + 1$ is updated by

$$\begin{cases} V_j^{Mc+1} = e^{-R.(Mc+1)}.V_j^{Mc} + rand.\left(D_g - D_j^{Mc}\right), \\ \qquad\qquad\qquad D_j^{Mc+1} = D_j^{Mc} + V_j^{Mc+1}, \end{cases} \tag{1}$$

where $V_j^{Mc}$and V_j^{Mc+1} represent j pigeon's velocities at iteration Mc and Mc +1, respectively, R shows map and compass factor, rand variable used for random number [0,1], Dg for global best position, and D_j^{Mc} is the pigeon's position at iteration Mc.

The navigation system of pigeon is presented by landmark operator when $Mc^1_{max} \le Mc \le Mc_{max}$ Where Mc_{max} for maximum iteration of PIO and fulfills the condition $Mc_{max} \le \log_2(N) + Mc^1_{max}$. The position function D_j^{Mc+1} is expressed as in the following equation:

$$\begin{cases} M = [M/2], \\ D^{Mc}_{center} = \dfrac{\sum_{i=1}^{M} D_j^{Mc}.\mu\left(D_j^{Mc}\right)}{\sum_{i=1}^{N}\mu\left(D_j^{Mc}\right)} \\ D_j^{Mc+1} = D_j^{Mc} + rand.\left(D^{Mc}_{center} - D_j^{Mc}\right) \end{cases} \tag{2}$$

where $[\cdot]$ is used for ceiling function. D^{Mc}_{center}, is the average weighted landmark positions at iteration Mc. The weight $\mu\left(D_j^{Mc}\right)$ is calculated by:

$$\mu\left(D_j^{Mc}\right) = \begin{cases} f\left(D_j^{Mc}\right), \text{for maximization}, \\ \dfrac{1}{f\left(D_j^{Mc}\right) + \varepsilon}, \text{for minimization}, \end{cases} \tag{3}$$

where$f\left(D_j^{Mc}\right)$ shows the cost function pigeon j at iteration Mc with any nonzero constant.

4. Pigeon inspired optimization and its variants

In the world of artificial intelligence, intelligent algorithms are needed to be changed time to time in order to maintain precise optimization and complex problem identifications. A number of optimization algorithms have been used to counter these problems such as Ant Colony Optimization (ACO), Genetic Algorithm (GA), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Pigeon Inspired Optimization (PIO) etc. have been widely used in many optimization problems. PIO is the state of the art optimization algorithm that was initially proposed for aerial robot path planning problems. Due to its simplicity and optimizing ability, PIO has been combined with other algorithms to avoid trapping into local optima as well as faster response. Furthermore, modifications in basic PIO algorithm based on structure, operation and application has been gathered in **Table 1** to review for motion planning of multiple agents. Year wise distribution of PIO variants are as follows.

In 2014, Duan and Qiao [10] introduced a novel optimization process termed as Pigeon Inspired Optimization (PIO) algorithm for path planning of aerial system. This novel algorithm comprises of multiple self-governing operators: map and compass operator for magnetic field effect of earth and landmark operator for remembering the route with the help natural behavior of homing pigeons. Zhang and Duan [11] proposed a novel Predator–prey pigeon-inspired optimization (PPPIO) for 3-D path planning problem solution of unmanned aerial vehicles (UAVs). Zhang and Duan [12] again proposed improved PIO: PPPIO for 3-D path planning of Uninhabited Combat Aerial Vehicle. Li and Duan [13] achieved low altitude target detection for UAVs with the help of hybrid algorithm of Simulated

DOI: http://dx.doi.org/10.5772/intechopen.9881

S. No	Ref	Title	technique used	applied on	compared with	key findings	limitations
1.	[10]	"Pigeon-inspired optimization: a new swarm intelligence optimizer for air robot path planning"	A new algorithm based on Pigeon's natural behavior namely Pigeon Inspired Optimization Algorithm (PIO)	UAVs	DE	• Faster convergence and optimize global search. • Generate smooth optimal path planning.	• Not for complex path planning problems. • PIO algorithm is not valid for confined ideal solution.
2.	[11]	"Predator–Prey Pigeon-Inspired Optimization for UAV Three-Dimensional Path Planning"	Pigeon Inspired Optimization with Predator Prey(PPPIO)	UAVs	PIO PSO	• Improved population diversity. • Increased the convergence speed.	• Not valid for high number of iterations Variations occurred after achieving stability.
3.	[12]	"Three-Dimensional Path Planning for Uninhabited Combat Aerial Vehicle Based on Predator–Prey Pigeon-Inspired Optimization in Dynamic Environment"	Prey–Predator PIO algorithm (PPPIO)	Uninhabited Combat Aerial Vehicle	PIO PSO DE	• Best cost function achieved of the system • Best efficiency and convergence speed achieved	• Insufficient for fixed-wing aircrafts • Application missing
4.	[13]	"Target detection approach for UAVs via improved Pigeon-inspired Optimization and Edge Potential Function"	Simulated Annealing based Pigeon Inspired Optimization algorithm with Edge Potential Function (SAPIO-EPF)	UAVs	GA PSO ABC PIO	• Enhance convergence speed. • Robust target detection of UAV at low altitude.	• Higher computational time due to image size. • Slower convergence speed than basic PIO
5.	[14]	"Pigeon-Inspired Optimization Approach to Multiple UAVs Formation Reconfiguration Controller Design"	Pigeon Inspired Optimization with Control Parameterization and Time Discretization (PIO-CPTD)	UAVs	PSO	• Achieved same height maneuvering • Capability to discover smaller value than PSO.	• Need extra calculations for discretization. • Achieved local minima after 600 iterations
6.	[15]	"Multiple UAVs Mission Assignment Based on Modified Pigeon-Inspired Optimization Algorithm"	Modified Pigeon Inspired Optimization (MPIO) algorithm	UAVs	PIO DE PSO	• Evaluation function performance is better. • Convergence speed is enhanced. • Improved global searching process.	• Premature convergence issue. • Inaccuracy occurred due to large number of iterations.
7.	[16]	"PID Controller Design Based on Prey–Predator Pigeon-Inspired Optimization Algorithm"	Prey–Predator PIO algorithm (PPPIO)	Plant System	PIO PSO	• Improved PID tuning. • Avoid trapping optimal solution.	• Step response is similar to PIO. • Parameters values similar to PSO.

S. No	Ref	Title technique used applied on compared with key findings limitations					
8.	[17]	"Bloch Quantum-behaved Pigeon-Inspired Optimization for Continuous Optimization Problems"	Bloch Quantum-behaved Pigeon Inspired Optimization (BQPIO)	Benchmark Function Problems	PSO QPSO PIO	• Achieved global minimum of the functions. • Optimal solution in less iteration.	• Valid for short reference only. • Non directional mutation operation caused slowed convergence
9.	[18]	"Gaussian pigeon-inspired optimization approach to orbital spacecraft formation reconfiguration"	Gaussian Pigeon Inspired Optimization (GPIO)	Orbital Spacecraft Formation	PSO PIO	• Simulation running time is smaller than PIO and PSO • Used Gaussian method for space craft formation reconfiguration	• The robustness value is just satisfied. • Achieved late fitness value than PSO and PIO
10.	[19]	"Pigeon-inspired optimization applied to constrained gliding trajectories"	Prey–Predator PIO algorithm (PPPIO)	Hypersonic Gliding Vehicles	PSO	• Generated the inhibited gliding route for hypersonic gliding vehicles. • Quick decision in flight's mission placement.	• Not feasible for uncertainties in complex environment • Results are same after 20 iterations.
11.	[20]	"Multi-objective pigeon-inspired optimization for brushless direct current motor parameter design"	Multi-objective PIO (MPIO)	BLDC motor	NSGA-II	• Improved pareto frontier obtained in parameter design. • Achieved more stability by introducing transition in operators.	• Inconsistence found in algorithm when used for BLDC
12.	[21]	"Robust Binocular Pose Estimation Based on Pigeon-Inspired Optimization"	PIO with Binocular pose estimation (PIO-BPnP)	Binocular Camera Systems	LHM MLHM RPnP BPnP	• Fine pose estimation received for binocular camera systems. • Minimized all types of errors. • Optimal results achieved in few iterations	• Too many simulations needed for average result • Inefficient because it needs all edge calculations.
13.	[22]	"Linear-quadratic regulator controller design for quadrotor based on Pigeon inspired optimization"	LQR based on PIO	Autonomous Aerial Refueling	PSO	• Best fitness value obtained • Estimated altitude achieved for quad rotor in least time.	• Energy cost increases due to constant R parameter.
14.	[23]	"A type of collective detection scheme with improved pigeon-inspired Optimization"	PIO with Expand and Contract concept (ECPIO) algorithm	Global Navigation Satellite Systems	PSO DE PIO	• Execution time is faster. • Complex multi-model functions outperformed performance of previous ones.	• Decision making process is missing • It's based on un real signals.

S. No	Ref	Title	technique used	applied on	compared with	key findings	limitations
15.	[24]	"Control parameter design for automatic carrier landing system via pigeon-inspired optimization"	Pigeon Inspired Optimization (PIO)	Automatic Carrier Landing System (ACLS)	BSO PSO ABC BA	• Expected pitch rate is achieved. • Best parameter tuning obtained for ACLS. • Fast convergence speed. • Minimum standard deviation.	• Initial parts are same when compared. • Only level 1 of control anticipation parameter is achieved.
16.	[25]	"Pendulum-like Oscillation Controller for UAV Based on Lévy-flight Pigeon-inspired Optimization and LQR"	Lévy Flight based PIO (LFPIO) algorithm for Linear-quadratic Regulator	UAVs	PIO PSO SAPSO	• More reliable in flight mode • Accuracy and convergence speed is much higher than PIO.	• Stability achieved after 20 iterations while other got before.
17.	[26]	"Pigeon inspired optimization approach to model prediction control for unmanned air Vehicles"	MPC controller with PIO algorithm	UAVs	PSO	• Best fitness value achieved in less than 10 iterations. • Reduced the parameter optimization burden from controller	• Step responses are same for PIO and PSO. • Still have capacity to improve in MPC controller.
18.	[27]	"Pigeon-inspired optimization and lateral inhibition for image matching of autonomous aerial refueling"	PIO with Lateral Inhibition (LI-PIO)	UAVs	PSO LI-PSO PIO	• Improved pre-processing images parameters i.e. contrast and edges. • Consume minimum time to execute	• PIO and LI-PIO have same stability 10th iteration • Results not included when the UAV tilted
19.	[28]	"A modified consensus algorithm for multi-UAV formation based on Pigeon inspired optimization with a slow diving strategy"	PIO with a Slow Diving Strategy	Multiple UAVs	PSO PIO	• Remove oscillations effectively and smooth the curve. • Achieved desired location with least fitness value.	• Sharp dive and quick climb may lead to crash. • Must remain at safe distance due to communication gap.
20.	[29]	"Active Disturbance Rejection Control for Small Unmanned Helicopters via Levy Flight-based Pigeon-inspired Optimization"	Lévy Flight pigeon-inspired optimization (LFPIO)	UAVs	PSO PIO	• Resolves altitude fluctuation problem in small unmanned helicopters.	• Step responses of angular and linear velocities approximately same.

S. No	Ref	Title	technique used	applied on	compared with	key findings	limitations
						• Optimized ADRC parameter to work best in complex environment.	• Small difference in lateral and longitudinal angular velocity step responses.
21.	[30]	“Aerodynamic Parameter Identification of Hypersonic Vehicle via Pigeon inspired Optimization”	Pigeon Inspired Optimization (PIO)	UAVs	PSO PIO	• Aerodynamic parameters identified with accuracy despite noise. • Minimum fluctuations in curve.	• PIO worked poor between 5 and 10 iterations. • Minimum difference in cost functions.
22.	[31]	“Biological object recognition approach using space variant resolution and pigeon-inspired optimization for UAV”	PIO with Space Variant Resolution mechanism (SVRPIO)	UAVs	GLPT-TM	• Computational complexity reduced due to optimized search approach. • With the help of rotational and scale challenges, object recognition is better.	• Efficiency is reduced when scaled twice. • Invalid run occurred when target moves in either side of coordinates simultaneously.
23.	[32]	“Flying Vehicle Longitudinal Controller Design via Prey–Predator Pigeon-Inspired Optimization”	Prey–Predator PIO algorithm (PPPIO)	Acceleration Control System	PIO PSO	• Faster response and no overshoot in designing a controller. • Improved normal acceleration performance	• Settling time is not suitable.
24.	[33]	“Fuzzy energy management strategy for parallel HEV based on pigeon-inspired optimization algorithm”	Quantum Chaotic Pigeon-Inspired Optimization (QCPIO) algorithm with Fuzzy approach.	Hybrid Electric Vehicle	Fuzzy PSO Fuzzy	• Reduced vehicle emission effectively • Improved fuel economy of vehicle. • Stable battery charging and discharging.	• Only applicable for low load area.
25.	[34]	“Lévy flight based pigeon-inspired optimization for control parameters optimization in automatic carrier landing system”	Lévy Flight based pigeon-inspired optimization	ACLS	PIO PSO DE	• Best landing track of aircraft in the presence of vertical wind disturbance. • Fewer fluctuations in angle of attack.	• DE lead in angle of attack with best fitness value for ACLS. • Took more time to remove the error

DOI: http://dx.doi.org/10.5772/intechopen.9881

S. No	Ref	Title	technique used	applied on	compared with	key findings	limitations
26.	[35]	"Automatic Carrier Landing System multilayer parameter design based on Cauchy Mutation Pigeon-Inspired Optimization"	Cauchy Mutation Pigeon-Inspired Optimization (CMPIO)	ACLS	PSO DE PIO	• Improved bandwidth dynamic characteristics i.e. flight path response. • Smallest overshoot and least fitness function	• High rise and settling time.
27.	[36]	"Adaptive Operator Quantum-Behaved Pigeon-Inspired Optimization Algorithm with Application to UAV Path Planning"	Quantum-behaved pigeon-inspired optimization (QPIO)	UAVs	PSO PIO	• Smooth path planning in the presence of threat sources. • Convergence speed is faster	• Lower altitude value as compared to PSO and PIO. • Searching time is higher than PIO.
28.	[37]	"Social-class pigeon-inspired optimization and time stamp segmentation for multi-UAV cooperative path planning"	Social Class PIO with Time Stamp Segmentation (SCPIO-TSS)	UAVs	PSO PIO	• Reduced coordination cost. • Explicit search optimization by modified landmark operator.	• Algorithm condition are not investigated • Slower convergence speed than PSO
29.	[38]	"Predator–Prey Pigeon-Inspired Optimization for UAV ALS Longitudinal Parameters Tuning"	predator–prey pigeon-inspired optimization (PPPIO) algorithm	UAVs	BBO, ES DE, PIO GA, StudGA	• Improved performance of flight path angle with nominal convergence speed. • Better integral value for ALS.	• Fluctuation in actual response of the proposed work. • Marginal stability exhibit by system.
30.	[39]	"A multi-objective pigeon-inspired optimization approach to UAV distributed flocking among obstacles"	multi-objective pigeon-inspired optimization (MPIO)	UAVs	MPIO NSGA-II	• Small population have fine Pareto frontier with few iterations. • Stable flight formation achieved	• Same curve for altitude and altitude rates. • Deadlock occurred in the convergence
31.	[40]	"Re-entry Trajectory Optimization using Pigeon Inspired Optimization Based Control Profiles"	Pigeon Inspired Optimization (PIO)	Spacecraft Launch Vehicles.	PSO	• Flew at upper bounds on load factor • Satisfactory entry trajectory as predicted	• Dynamic pressure of the system avoided. • Heart rate and initial flight path angle is slightly higher.
32.	[41]	"Mixed Game Pigeon-Inspired Optimization For Unmanned Aircraft System Swarm Formation"	Mixed Game Pigeon-Inspired Optimization (MGPIO)	Multiple UAVs	PIO PSO	• Stable formation with faster convergence. • System successfully avoided local minima.	• Chances of collision still present • Applied only on six UAV's.

S. No	Ref	Title	technique used	applied on	compared with	key findings	limitations
33.	[42]	"Coevolution Pigeon-Inspired Optimization with Cooperation-Competition Mechanism for Multi-UAV Cooperative Region Search"	coevolution pigeon-inspired optimization (CPIO) algorithm	multi-UAV cooperative search (MUCS)	PIO PSO GA	• Convergence speed is faster. • Best average number of target found among all	• Not suitable for large number of iterations
34.	[43]	"A pigeon-inspired optimization algorithm for many-objective optimization problems"	multi-objective pigeon inspired optimization (MPIO)	Multi Objective Optimization	NSGAIII GrEA HypE KnEA MOEA/D	• Stability and convergence speed is improved. • Best diversity achieved.	• Pareto fronts obtained from NSGA-III and MOEA/D are better than MaPIO.
35.	[44]	"Discrete pigeon-inspired optimization algorithm with Metropolis acceptance criterion for large-scale traveling salesman problem"	Discrete PIO (DPIO)	Float and Integer Distances	ESACO MAS SOM	• Improved performance of TSP. • Avoid premature convergence by modifying PIO basic operators.	• It cannot be implemented on large scale due to need of centralized access of data. • Need of fine-tuned parameters of DPIO.
36.	[45]	"Mobile Robot ADRC with an Automatic Parameter Tuning Mechanism via Modified Pigeon-inspired Optimization"	Evolutionary Game based PIO (EGPIO)	the deformable push rod	PIO PSO CPIO	• This method yields a minor steady-state error in overall angle output. • Settling time index is best among all.	• No convergence proof is given. • Kinematic limitations have been ignored in this method.
37.	[46]	"Dynamic Discrete Pigeon-inspired Optimization for Multi-UAV Cooperative Search-attack Mission Planning"	Dynamic Discrete PIO Algorithm (D^2PIO)	Multiple Unmanned Aerial Vehicles	PSO, BPSO, PIO,BPIO DPSO, MPSO	• Proposed method performed well as compared to others. • Task switching ability included in this research.	• Task completeness gradually decreasing due to frequent task switching. • Population size increment may lead to higher computational cost
38.	[47]	"Limit-Cycle-Based Mutant Multi-objective Pigeon-Inspired Optimization"	Limit-Cycle-based Mutant Multi-Objective Pigeon-Inspired Optimization (CMMOPIO)	Multi-Objective Optimization Algorithms	CMOPIO, MOPSO, NSGA-II, SPEA2, MOEA-D	• The faster convergence speed and avoid trapping into local optimum due to mutation mechanism. • Improved population diversity with wider search space.	• Real world problems • Performance of algorithm

DOI: http://dx.doi.org/10.5772/intechopen.9881

S. No	Ref	Title technique used applied on compared with key findings limitations					
39.	[48]	"Multi-UAV obstacle avoidance control via multi-objective social learning pigeon-inspired optimization"	Multi-objective Social Learning Pigeon-Inspired Optimization (MSLPIO)	Unmanned Aerial Vehicle formation	MPIO NSGA-II	• Improved flocking control during flight. • Desired Yaw angle achieved • Great obstacle avoidance were seen	• Convergence speed seems poor • Some UAV's deviated from swarm when passed through obstacles.
40.	[49]	"A Binary Tree Based Coordination Scheme for Target Enclosing with Micro Aerial Vehicles"	Multi-UMAV target enclosing problem based on binary-tree communication topologies	Unmanned Micro Aerial Vehicle (UMAV)	UAV's	• Despite frequent variation in target direction proposed scheme is able to for stable formation. • Able to cover target at any nominal height.	• The method has some detection failure due to fixed communication among UAV's. • UMAV must have extraordinary flexibility.
41.	[50]	"A multi-strategy pigeon-inspired optimization approach to active disturbance rejection control parameters tuning for vertical take-off and landing fixed-wing UAV"	Multi-Strategy Pigeon-Inspired Optimization (MSPIO) algorithm	UAVs	PSO GA PIO CMPIO	• Solved the height fluctuation problem during forward flight of fixed wing UAV. • Hovering, dynamic inheritance to optimize better efficiency with improved search ability.	• Huge power required for transition. • No stability analysis have done.
42.	[51]	"A novel adaptive pigeon-inspired optimization algorithm based on evolutionary game theory"	adaptive pigeon-inspired optimization algorithm Evolutionary game theory (EGT)	pigeons	PIO CPIO CMPIO SCPIO	• Global optimization achieved with good convergence speed. • The system becomes stable after 50 iterations, which is good.	• Almost identical mean error curve for the Schwefel's function between CPIO and EGTPIO. • It does not support theoretical aspect
43.	[52]	"Autonomous trajectory tracking of a quadrotor UAV using ANFIS controller based on Gaussian pigeon-inspired optimization"	GPIO algorithm based on adaptive neuro-fuzzy inference system (ANFIS)	3-DOF quadrotor	PID	• Followed the reference trajectory at above 90% accuracy. • Convergence speed and stability also superior to classical method.	• Instability may occur in higher iterations

Table 1.
Comparative analysis of pigeon inspired optimization and its variants for motion planning.

Annealing Pigeon-inspired Optimization (SAPIO) and Edge Potential Function (EPF). Zhang and Duan [14] proposed a controller for formation reconfiguration problems of multiple unmanned aerial vehicles (UAVs). Hao et al. [15] linked PIO with energy consumption of UAV mission assignment. Sun and Duan [16] used PPPIO for Proportion-Integral-Derivative (PID) controller parameter adjustment. Li and Duan [17] proposed Bloch Quantum Behaved Pigeon-Inspired Optimization (BQPIO) to enhance the local search and position uncertainty.

In 2015, Shujian and Duan [18] presented another algorithm called improved pigeon-inspired optimization (PIO) algorithm of multiple orbital spacecraft formation problem. Jiang et al. [19] utilized PIO algorithm for the velocity-dependent bank angle profiles of the reentry vehicle. Hua et al. [20] used brushless DC motor parameters optimization via Multi-objective Pigeon Inspired Optimization (MPIO). Gan and Duan [21] presented a robust algorithm based on PIO for binocular pose estimation of multiple camera systems (MCS). Sun et al. [22] worked on PIO-based LQR controller for quad-rotor for autonomous aerial refueling (AAR). Zheng [23] proposed a new structure of CD for detection Global Navigation Satellite Systems (GNSS) signals and location by using improved pigeon-inspired optimization. Deng and Duan [24] presented a novel control parameter design method for the Automatic Carrier Landing System (ACLS) via PIO.

In 2016, Liu and Duan [25] developed a new Lévy -flight pigeon-inspired Optimization (LFPIO) algorithm for pendulum like oscillation controller in UAVs for optimality of LQR with accuracy, convergence speed and reliability. Dou and Duan [26] proposed PIO algorithm for parameter optimization in model prediction control (MPC) for unmanned air vehicles. Sun and Duan [27] showed a hybrid algorithm of lateral inhibition with pigeon inspired optimization (LI-PIO) autonomous aerial refueling (AAR) image matching problem.

In 2017, Zhang and Duan [28] proposed a new algorithm Slow Driving Strategy Pigeon Inspired Formula (SD-PIO) for Consensus. Zhang et al. [29] presented a novel algorithm LFPIO for active disturbance rejection control (ADRC) method applied on small unmanned helicopters. Xeu and Duan [30] opted PIO algorithm for aerodynamics parameters of hypersonic vehicles. Long and ning [31] proposed a novel global log-polar transformation (LPT) based template-matching algorithm (GLPT-TM) along with PIO for biological object recognition. Mohammad and Duan [32] developed Flying Vehicle Longitudinal Controller Design with the help of.

Prey–Predator Pigeon-Inspired Optimization (PPPIO), Zheng, et al. [33] proposed Quantum Chaotic Pigeon Inspired Optimization (QCPIO) algorithm for fuzzy control strategy of Hybrid Electric Vehicle (HEV). Dou and Duan [34] utilized a LFPIO for controlling the parameters of ACLS.

In 2018, Yang et al. [35] presents a novel algorithm Cauchy Mutation Pigeon Inspired Optimization (CMPIO) for the design problem of ACLS. Hu et al. [36] proposed Adaptive Operator Quantum-Behaved Pigeon-Inspired Optimization (AOQPIO) algorithm for UAV 3-D path planning problem. Zhang and Duan [37] proposed Social Class Pigeon Inspired Optimization (SCPIO) with Time Stamp Segmentation (TSS) for multi-UAV cooperative path planning. Duan et al. [38] used PPPIO optimization algorithm to improve the tracking control of the fixed-wing UAV. Qiu and Duan [39] applied MPIO for stable formation of UAV's in complex environment. Sushnigdha and Joshi [40] solved re-entry trajectory optimization problem of Spacecraft and launch vehicles by using PIO.

In 2019, Duan et al. [41] used Mixed Game Pigeon Inspired Optimization (MGPIO) algorithm for swarm formation of Unmanned Aircraft System (UAS). Luo et al. [42] proposed coevolution pigeon-inspired optimization (CPIO) algorithm for unmanned aerial vehicle (UAV) cooperative region search. Cui et al. [43] proposed a many-objective pigeon inspired optimization (MaPIOs) algorithm for multi-UAV cooperative region search. Zhong et al. [44] established discrete PIO (DPIO) algorithm for Traveling Salesman Problems (TSPs). Hai and Duan [45] proposed Evolutionary Game Theory based Pigeon Inspired Optimization (EGPIO) for autonomous mobile robot to boost ADRC method for the attitude deformation system.

In 2020, Duan et al. [46] proposed a Dynamic Discrete Pigeon Inspired Optimization (DDPIO) algorithm to solve a mission planning problem of search and attack of multiple UAVs. Duan et al. [47] presented Limit-Cycle-based Mutant Multi-Objective Pigeon-Inspired Optimization (CMMOPIO) to balance the global exploration and local exploitation. Ruan and Duan [48] proposed an improved PIO namely Multi-objective Social Learning Pigeon-Inspired Optimization (MSLPIO) for obstacle avoidance problem of Multi-UAV. Duan and Zhang [49] proposed coordination scheme for target enclosing based on binary tree for MUAV's.

In 2021, He and Duan [50] used a Multi-Strategy Pigeon-Inspired Optimization (MSPIO) algorithm to employ ADRC fluctuation problem HAI, et al. [51] utilized EGPIO algorithm to increase accuracy among pigeons. Selma et al. [52] mixed ANFIS controller with Gaussian pigeon-inspired optimization for autonomous trajectory tracking of a quad rotor UAV.

Above discussion is based on the improvements and modifications of basic PIO algorithms in each corresponding year. It can be seen that each year PIO, its modification and hybrid model become top trend in optimization related issues especially for the motion planning of various agents. For hybrid models, combination of other bio-inspired algorithm like ACO, GA etc. with PIO still lacking in this area.

5. Conclusion

Today, optimization algorithms are being widely used for the motion planning of complex optimization problems i.e. clusters, swarms and multi-objective by research scholars. Mostly, bio-inspired algorithms along with its variants have been proposed to increase the convergence speed and overall stability of the system. A novel bio-inspired optimization algorithm namely Pigeon Inspired Algorithms and its hybrid models are outperforming other related algorithm in terms of optimal motion planning techniques. This article manipulates recent trends of Pigeon Inspired Optimization algorithm and its modification for motion planning problems of agents. The dominance of PIO along with its hybrid model, an estimation mechanism must be developed in order to point of the importance over other bio inspired optimization algorithms. This study will help researcher to choose proper PIO variant for unexplored problem identification in complex environment where other known algorithm becomes failure. For future work, application based review or survey might be suitable for readers with hybrid model approach. Also work can be split into many parts based on path planning, formation control and self-organization of distributed systems.

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