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Novel modified Chernobyl disaster optimizer for controlling DC motor

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ABSTRACT

This article presents the modified Chernobyl disaster optimizer (CDO) method for DC motor control to find the optimal proportional integral derivative (PID) settings. DC motors are widely used machinery. DC motors are also simple to use. The detonation of the Chernobyl nuclear reactor core served as the inspiration for the idea and guiding principles of the CDO. CDO has limitations in the stability of exploration and exploitation areas. This research aims to obtain a new balance of exploration and exploitation. This study suggests incorporating the levy flight and chaotic algorithm (CA) techniques to enhance the CDO method. This study was conducted with the MATLAB/Simulink software. A comparative technique, which included the marine predator algorithm (MPA), golden jackal optimization (GJO), and CDO, was utilized to determine the performance of the MCDO method. According to the study's findings, the MCDO method's overshoot value outperformed all other approaches.

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1. INTRODUCTION

Process automation is becoming more and more necessary in various domains due to the industrial sector. Automation leads to higher output, better quality, and lower costs [1]–[4]. Up until a few decades ago, variable speed drives had a number of drawbacks, including high sizes and low efficiency. But better times came with the introduction of power electronic circuits, and today there are smaller, more dependable, and highly efficient variable drive systems available [5]–[7]. Electrical devices are essential to robotics and control systems [8]–[10]. The DC motor is a widely used electrical device that transforms electrical energy into mechanical energy in a variety of industrial settings. One of the many benefits of DC motors is their ability to control speed both instantly and continuously. Due to these advantages, they can be used in a wide range of applications, such as robotic manipulators, electric cars, pumps, home appliances, electric cranes, and steel rolling mills [11]. A power conversion device that transforms electrical energy into mechanical energy is a DC motor [12]–[14]. Intentional changes in speed can be made manually or automatically. This is known as speed control. Excellent speed control is provided by the DC motor's ability to accelerate and decelerate. The torque characteristics of the DC motor are higher as compared to the AC motor speed. The speed control range of DC motors can be adjusted for extended periods of time. Attributes of a DC motor that are easily maintained to provide great performance and ease of control. A few DC motor controls, both traditional and computerized, have been shown.

Various controllers are employed for regulating the speed of DC motors, with the traditional controllers proportional-integral (PI) and proportional-integral-derivative (PID) being the most frequently utilized [15], [16]. However, PID controllers also possess significant limitations, such as their susceptibility to variations in controller gains Ki and KP, inadvertent speed overshoot, and sluggish response to abrupt fluctuations in load torque [17]–[19]. The performance of the controller is contingent upon the level of accuracy exhibited by the system models and parameters. Hence, there is a requirement for a controller that can overcome the limitations of PID controllers. The PID design with a metaheuristic algorithm is widely adopted across numerous sectors as a prominent methodology. The regulation of DC motor speed has been extensively studied using metaheuristic techniques. Numerous uses for the most recent metaheuristic techniques are demonstrated, including: smell agent optimization algorithm [20], equilibrium optimizer [21], artificial bee colony (ABC) algorithm [22], grey wolf optimization algorithm [23]–[26], harmony search algorithm [27], [28] and nelder-mead algorithm [29].

Numerous studies have been conducted on the topic of PID optimization in DC motors. The field of PID optimization remains largely unexplored, particularly in relation to the utilization of contemporary optimization techniques. This paper introduces a novel optimization method, known as the modified chernobyl disaster optimizer (MCDO), which is utilized for the estimation of PID parameters in the context of DC motor control. The concept and fundamental principles of the Chernobyl disaster optimizer (CDO) were derived from the explosion of the Chernobyl nuclear reactor core [30]. The contributions of this research are:

- Improvement of the CDO method by making modifications to combine it with the levy and chaotic methods.
- Application of the MCDO method to DC motors.
- Validate MCDO performance with marine predator algorithm (MPA), golden jackal optimization (GJO), and CDO using benchmark function and DC motor performance.

This paper’s structure is the second section that discusses the DC motor and MCDO approach. Results and discussion make up the third section. Conclusions are drawn in the final section.

2. METHOD

2.1. Chernobyl disaster optimizer

The Chernobyl nuclear reactor core explosion served as the model and inspiration for the CDO idea and basic principles. Nuclear instability causes radioactivity in CDO, causing the nucleus to emit a variety of radiation types. The terms “gamma, beta, and alpha particles” refer to the three most prevalent forms of radiation. Following the explosion of reactor number four, three particles as previously indicated assault humans. Three different forms of radiation-beta, gamma, and alpha-are released from nuclei upon explosion. The disaster will occur in the low-pressure area that is inhabited by humans, after these particles have travelled far from the reactor’s core (a high-pressure area). Presumably, these particles are targeting the humans who are the victims when they are on foot. Like other metaheuristic methods, it has the characteristic of searching space. CDO finds the initial search space using:

$$X = \begin{bmatrix} x_{1,i} & \cdots & x_{1,Dim-1} & x_{1,Dim} \\ x_{2,i} & \cdots & \cdots & x_{2,dim} \\ \vdots & \vdots & \vdots & \vdots \\ x_{N,i} & \cdots & x_{N,Dim-1} & x_{N,Dim} \end{bmatrix} \quad (1)$$

where, $x_{1,i}$ indicates the decision value (position), N is the amount of population, and Dim indicates the dimension of the issue.

$$X_{ij} = Rand \times (UB_j - LB_j) + LB_j \; ; \; i = 1,2, \ldots .. N \; ; \; j = 1,2, \ldots . dim \quad (2)$$

Where $Rand$ is a disordered amount, LB_j is the jth lower limit, and UB_j is the j the upper limit.

Gamma particle: when assaulting humans, it can compute the gamma particle's gradient descent factor (V_γ) using (3) to (8).

$$V_\gamma = (X_\gamma(t) - \rho_\gamma \Delta_\gamma) \quad (3)$$

$$\rho_\gamma = \frac{x_h}{s_\gamma} - (WS_h . rand()) \quad (4)$$

$$X_h = r^2.\pi \tag{5}$$

$$S_\gamma = \log\left(rand(1{:}\,300.000)\right) \tag{6}$$

$$\Delta_\gamma = \left|A_\gamma.X_\gamma(t) - X_T(t)\right| \tag{7}$$

$$A_\gamma = r^2.\pi \tag{8}$$

Where $X_\gamma(t)$ is the present location of γ. ρ_γ is the dissemination of (γ); Δ_γ is difference position in γ. X_h is area of human walking, S_γ is the speed of (γ) particle. The value of r is selected at random. A_γ is area of propagation of gamma particle. X_T is the mean values of all positions.

Beta particle: when assaulting humans, it can compute the learning rate of the β using (9) to (13).

$$V_\beta = 0.5(X_\beta(t) - \rho_\beta\Delta_\beta) \tag{9}$$

$$\rho_\beta = \frac{X_h}{0.5.S_\beta} - (WS_h.rand()) \tag{10}$$

$$S_\beta = \log\left(rand(1{:}\,270.000)\right) \tag{11}$$

$$\Delta_\beta = \left|A_\beta.X_\beta(t) - X_T(t)\right| \tag{12}$$

$$A_\beta = r^2.\pi \tag{13}$$

Where $X_\beta(t)$ is the present location of β; ρ_β is the dissemination of β; Δ_β is the difference position in β. X_h is the area of human walking, S_β is the speed of (β) particle. A_β is the location of dissemination of β.

Alpha particle: when attacking a human, it can compute the learning rate of the α using (14) to (18).

$$V_\alpha = 0.25(X_\alpha(t) - \rho_\alpha\Delta_\alpha) \tag{14}$$

$$\rho_\alpha = \frac{X_h}{0.25.S_\alpha} - (WS_h.rand()) \tag{15}$$

$$S_\alpha = \log\left(rand(1{:}\,16.000)\right) \tag{16}$$

$$\Delta_\alpha = |A_\alpha.X_\alpha(t) - X_T(t)| \tag{17}$$

$$A_\alpha = r^2.\pi \tag{18}$$

Where $X_\alpha(t)$ is the present location of α; ρ_α is the dissemination of (α) particle; Δ_β is the difference between human position and position of alpha particles. X_h is the area of human walking, S_α is the speed of (α) particle. A_α is the area of dissemination of α. The following calculation can be used to calculate the average of these particles' total speeds based on Galileo Galilei's in (19).

$$X_T = \frac{(V_\alpha + V_\beta + V_\gamma)}{3} \tag{19}$$

2.2. DC motor

The DC motor possesses the features of a single control system with dual control modes. The first mode, known as armature control mode, has a constant field current. nevertheless, has a set armature current and is referred to as a field control mode [31], [32]. Figure 1 illustrates the characteristics of a DC motor, which include resistance, inductance, and reverse electromotive force voltage. Details of the DC motor used in this research can be seen in Table 1. Armature resistance and inductance are represented by R_a and L_a, respectively. The electromotive force in reverse is e_b.

$$V_a(s) = (R_a + L_a.s).I_a(s) + e_b(s) \tag{20}$$

$$e_b(s) = K_b\omega(s) \tag{21}$$

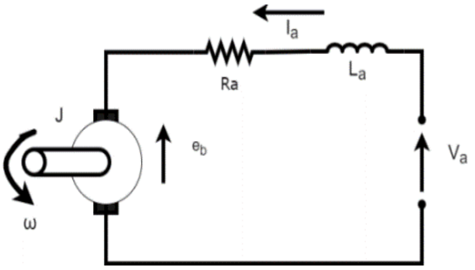


Figure 1. Illustration DC motor circuit

Table 1. DC motor parameters

Parameter	Value
K_b	0.05 V.s
L_a	2 H
R_a	0.4 Ω
J	0.0004 kg.m^2
B	0.0022 N ms/rad
K_M	0.015 N m/A

3. PROPOSED MODIFIED CHERNOBYL DISASTER OPTIMIZER

CDO has constraints in the stability of both exploration and exploitation domains. The objective of this research is to achieve a novel equilibrium between exploration and exploitation. This research proposes improvements to the CDO method by adding the levy flight method and chaotic algorithm (CA). Lévy flights are a particular class of general random walks in which the stride length during walking is described by a "heavy-tailed" probability distribution [33]. The Lévy distribution is as:

$$Levy(\alpha) = 0.05 \times \frac{x}{|y|^{1/\alpha}} \tag{22}$$

$$x = Normal\ (0, \sigma_x^2) \tag{23}$$

$$y = Normal\ (0, \sigma_x^2 \tag{24}$$

$$\sigma_x \ = \left[\frac{\Gamma(1+\alpha)\sin(\frac{\alpha\pi}{2})}{\Gamma\left(\frac{(1+\alpha)}{2}\right)\alpha\, 2^{\frac{(\alpha-1)}{2}}}\right]^{1/\alpha} and\ \sigma_x \ = 1 \text{ dan } \alpha = 1.5 \tag{25}$$

where x and y are two normally distributed variables with standard deviations σ_x and σ_y. Rather than using random variables, CA uses chaotic variables. Ergodistic and non-reinforcing properties characterize chaos. Furthermore, the search system is faster than stochastic or probability-based search techniques [34]. This paper employs logistics, a 1-D non-reversed map, as a chaotic set algorithm. To get to the optimal position, modification is employed to quicken the convergence curve's level.

$$ylog_{(i+1)} = a \times ylog_{(i)}\left(1 - ylog_{(i)}\right) \tag{26}$$

The (22) is put into (2) to become (27).

$$X_{ij} = Rand\ \times \left(UB_j - LB_j\right) + LB_j \times Levy(\alpha) \tag{27}$$

The (26) is inserted into (19) to become (28).

$$X_T = ylog_{(i+1)} \times \frac{(V_\alpha + V_\beta + V_\gamma)}{3} \tag{28}$$

The ideal value of the transient condition is obtained by adjusting the adaptive control parameters. The PID parameters in this study, which are K_p, K_i, and K_d, are obtained using the MCDO approach. Figure 2 shows a procedure of MCDO.

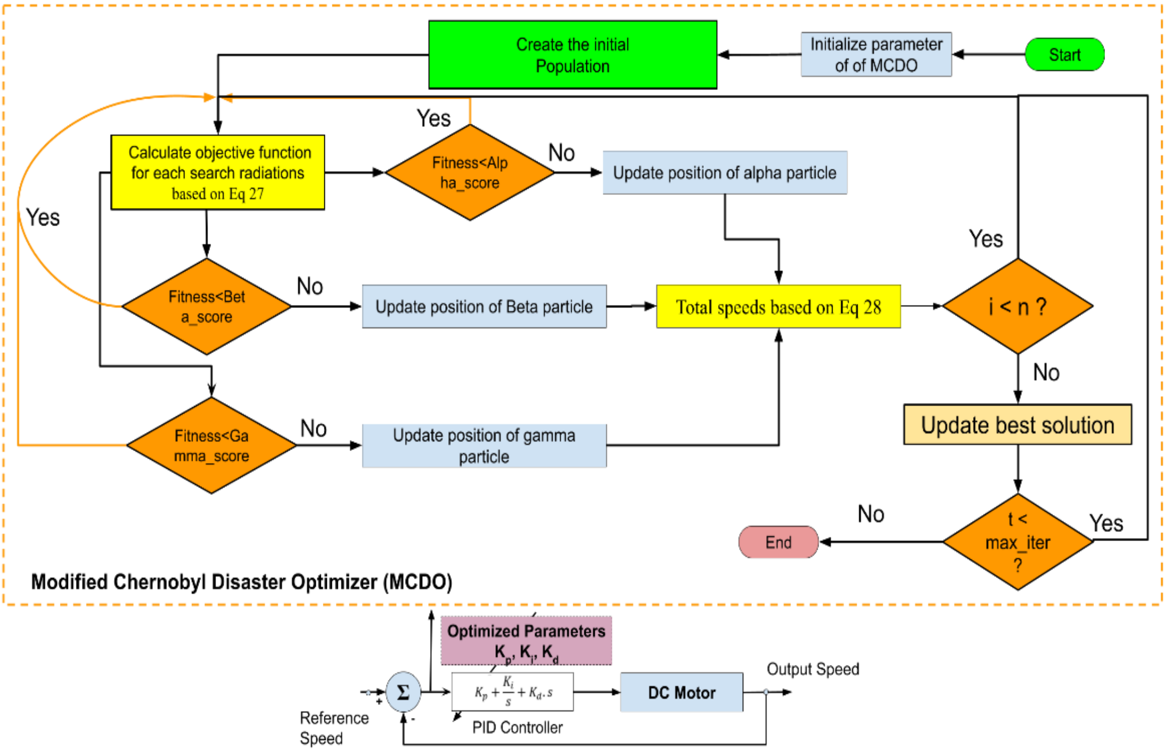


Figure 2. Proposed method MCDO

4. RESULTS AND DISCUSSION

4.1. Convergence curve profile

The MCDO algorithm code was completed and simulated on a laptop with a 3.1 GHz AMD A9-9425 processor and 4 GB of RAM. MATLAB/Simulink is the program that is utilized. Table 2 shows specifics of the MCDO parameters. Performance evaluation of the suggested approach MCDO-PID compares the MPA, CDO, and GJO approaches using the global optima function. The comparison’s outcomes are displayed in Table 3. Mathematical functions consist of 7 unimodal F1-F7, 6 multimodal F8-F13, and 10 fixed-dimensional multimodal functions F14-F21. The simulation results of the unimodal function can be seen in Figure 3 (see in APPENDIX). Figures 3(a) F1, 3(b) F2, 3(c) F3, 3(d) F4, 3(e) F5, 3(f) F6, and 3(g) F7. Multimodal functions are very useful for assessing exploration and reducing the local optimal position of an algorithm because the algorithm has many local optimal points. The results of the multimodal function simulation can be seen in Figures 3(h) F8, 3(i) F9, 3(j) F10, 3(k) F11, 3(l) F12, and 3(m) F13. Meanwhile, the simulation results of multimodal functions with fixed dimensions can be seen in Figures 3(n) F14, 3(o) F15, 3(p) F16, 3(q) F17, 3(r) F18, 3(s) F19, 3(t) F20, and 3(u) F21.

Table 2. The parameters of MCDO

Variable	Value
S_γ	Rand (1, 300,000) km/s
S_β	Rand (1, 270,000) km/s
S_α	Rand (1, 16,000) km/s
Size of population	25

Table 3. The result Of PID value

Method	K_p	K_i	K_d
PID	3.44	9.9239	0.51
MPA	2.3549	2.3549	1.4887
GJO	3.6111	9.8885	0.5693
CDO	3.7422	10.0000	0.5216
MCDO	3.6182	10	0.5611

The MCDO functions F1, F2, F3, F4, F5, F6, F7, F10, F11, F12, F13, F14, and F15 have the lowest convergence curves in Figures 3(a) to 3(f), 3(f)6, 3(g)F7, 3(i) F9, 3(j) F10,3 (k) F11, 3(l) F12, 3(m), F13, 3(n) F14, and 3(o) F15). Nonetheless, the MPA method has the lowest convergence value for F8, F19, F20, and F21. Figures 3(h) F8, 3(s) F19, 3(t) F20, and 3(u), F21 show it. The integral total weighted absolute value error (ITAE) and the integral total time-weighted square of error (ITSE) are used in the MCDO-PID method's performance measurement. The (29) and (30) are the formulas for ITSE and ITAE.

$$ITAE = \int_0^\infty t.e(t).dt \tag{29}$$

$$ITSE = \int_0^\infty t.e^2(t).dt \tag{30}$$

The starting reference for a DC motor is 1 pu from 1 to 5 seconds. At 5 seconds, the DC motor reference value increases to 1.5 pu. This value lasts until the 10th second. Then at the 10th second, the reference value drops to 0.75 pu. DC motor speed reaction output for PID, MPA-PID, GJO-PID, CDO-PID, and MCDO-PID controllers is shown in Figure 4. Transient response analysis of PID, MPA-PID, GJO-PID, CDO-PID, and MCDO-PID can be seen in Table 4. From the comparison of overshoot values presented in Table 4, the ITAE MCDO-PID value for this method shows the lowest value among the other methods, namely 0.002. Meanwhile, the CDO method has the highest overshot of 0.015.

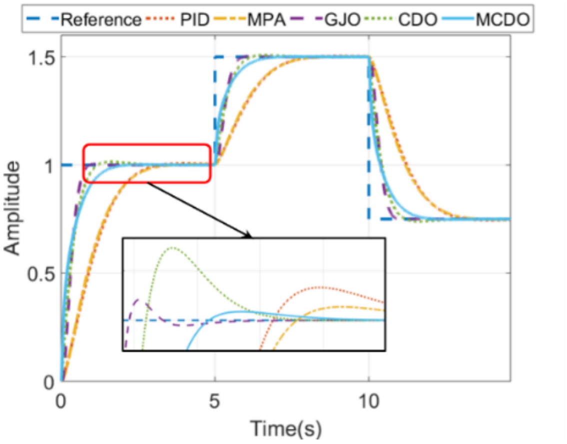


Figure 4. Speed response from each algorithm

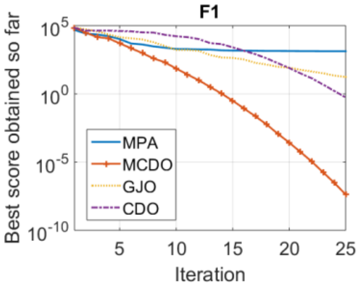
Table 4. Result when reference speed 1 pu

Controller	Overshoot	Rise time	ITSE	ITAE
PID	0.007	1.073	0.1676	0.5249
MPA-PID	0.003	1.014	0.1666	0.5230
GJO-PID	0.004	0.293	0.1826	0.5520
CDO-PID	0.015	0.382	0.1804	0.5486
MCDO-PID	0.002	0.363	0.1756	0.5399

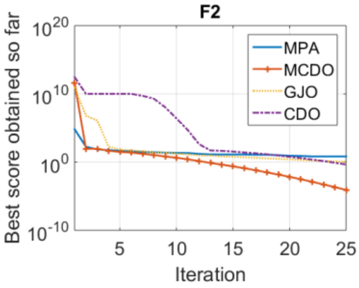
5. CONCLUSION

DC motor control is one of the most popular fields because DC motors are one of the most widely used and easy to implement control equipment. In this article, DC motor control is presented using the MCDO method. The CDO method was inspired by the explosion of the Chernobyl nuclear reactor core as a model and inspiration for basic ideas and principles. This research proposes improvements to the CDO method by adding the levy flight and CA methods. From the results of experiments with optimal functions, the MCDO method has the ability to reach wider exploration and exploitation. Meanwhile, the application of the MCDO method as a DC motor controller provides the best overshoot response value. The ITSE and ITAE values of the MCDO method are 2.661% and 1.611% better. compared to the CDO method.

APPENDIX



(a)



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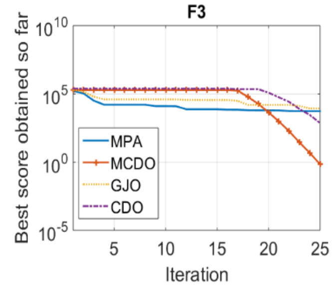

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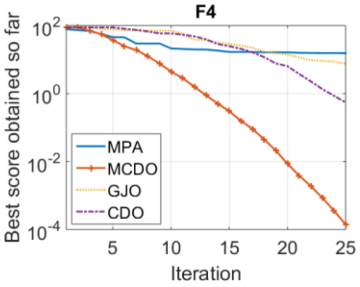

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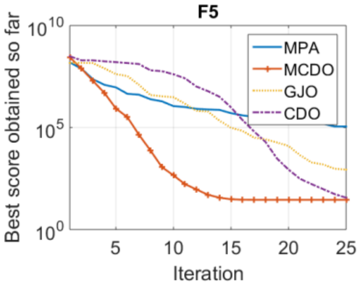

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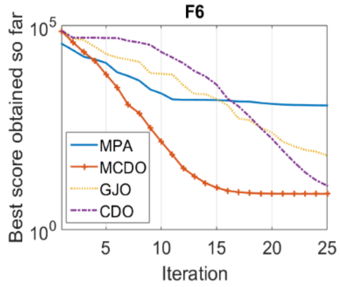

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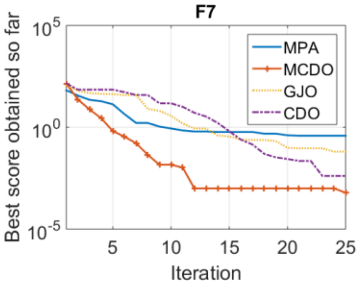

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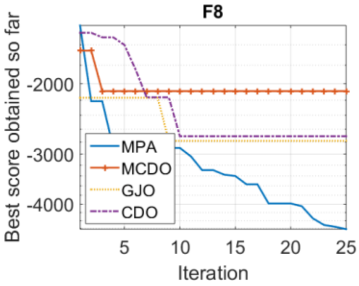

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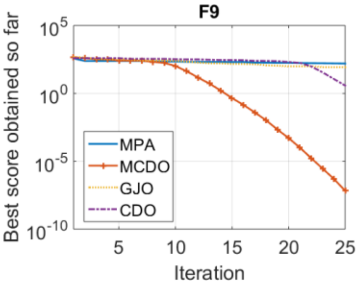
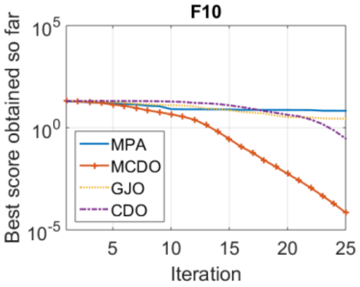


(i)



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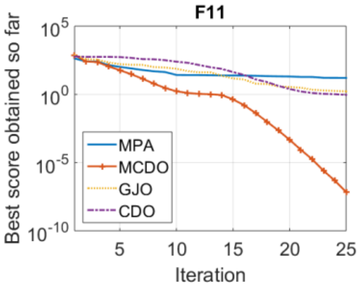

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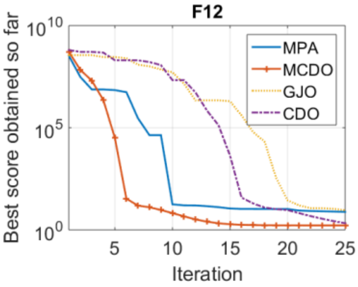

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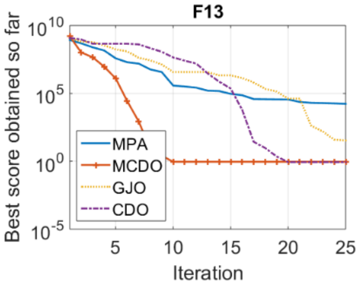

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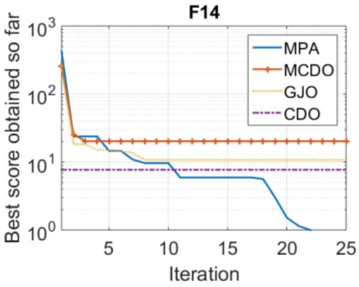

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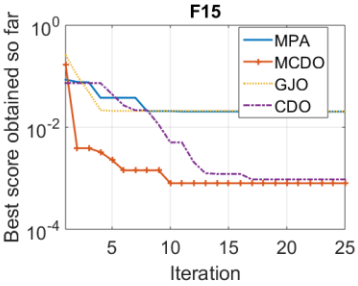
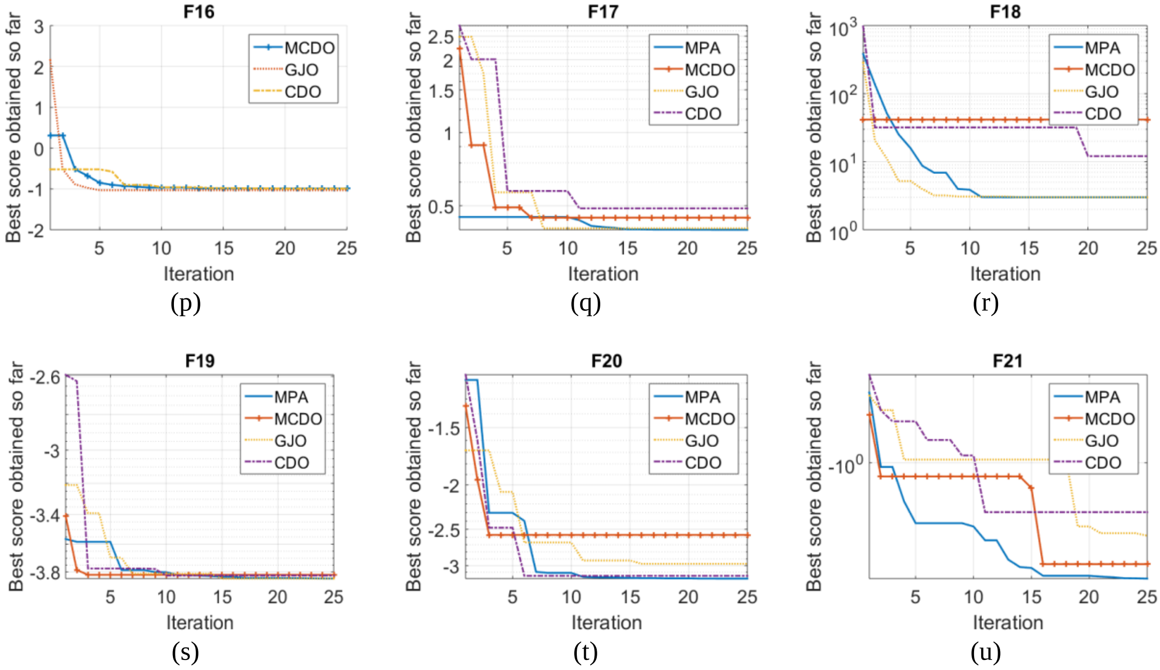


(o)



(p) (q) (r)

(s) (t) (u)

Figure 3. The convergence curve of benchmark function: (a) F1, (b) F2, (c) F3, (d) F4, (e) F5, (f) F6, (g) F7, (h) F8, (i) F9, (j) F10, (k) F11, (l) F12, (m) F13, (n) F14, (o) F15, (p) F16, (q) F17, (r) F18, (s) F19, (t) F20, and (u) F21

REFERENCES

[1] M. Attaran, "The impact of 5G on the evolution of intelligent automation and industry digitization," *Journal of Ambient Intelligence and Humanized Computing*, vol. 14, no. 5, pp. 5977–5993, 2023.

[2] M. Golovianko, V. Terziyan, V. Branytskyi, and D. Malyk, "Industry 4.0 vs. Industry 5.0: Co-existence, transition, or a hybrid," *Procedia Computer Science*, vol. 217, pp. 102–113, 2022, doi: 10.1016/j.procs.2022.12.206.

[3] H. O. Khogali and S. Mekid, "The blended future of automation and AI: examining some long-term societal and ethical impact features," *Technology in Society*, vol. 73, p. 102232, 2023.

[4] W. Aribowo and B. Suprianto, "Dingo optimization algorithm for designing power system stabilizer," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 1, pp. 1–7, Jan. 2023, doi: 10.11591/ijeecs.v29.i1.pp1-7.

[5] A. Lidozzi, M. Di Benedetto, T. A. Meynard, and L. Solero, "Medium-voltage seven-level multiplexed converter for AC applications," *IEEE Open Journal of Power Electronics*, vol. 4, pp. 81–90, 2023, doi: 10.1109/OJPEL.2023.3237877.

[6] K. Laadjal, F. Bento, K. Henriques, A. J. M. Cardoso, and M. Sahraoui, "A novel indicator-based online diagnostics technique of interturn short-circuit faults in synchronous reluctance machines," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 11, no. 3, pp. 3492–3501, 2023, doi: 10.1109/JESTPE.2023.3234339.

[7] S. Rahimpour, O. Husev, D. Vinnikov, N. V. Kurdkandi, and H. Tarzamni, "Fault management techniques to enhance the reliability of power electronic converters: an overview," *IEEE Access*, vol. 11, pp. 13432–13446, 2023, doi: 10.1109/ACCESS.2023.3242918.

[8] Z. Zhang *et al.*, "Fatigue-resistant conducting polymer hydrogels as strain sensor for underwater robotics," *Advanced Functional Materials*, vol. 33, no. 42, p. 2305705, 2023, doi: 10.1002/adfm.202305705.

[9] V. K. Awaar, P. Jugge, S. T. Kalyani, and M. Eskandari, "Dynamic voltage restorer–a custom power device for power quality improvement in electrical distribution systems," in *Power Quality: Infrastructures and Control*, Springer, 2023, pp. 97–116.

[10] D. Izci, S. Ekinci, H. L. Zeynelgil, and J. Hedley, "Performance evaluation of a novel improved slime mould algorithm for direct current motor and automatic voltage regulator systems," *Transactions of the Institute of Measurement and Control*, vol. 44, no. 2, pp. 435–456, Jan. 2022, doi: 10.1177/01423312211037967.

[11] M. Hilal, H. ALRikabi, and I. A. Aljazaery, "A control system of DC motor speed: systematic review," *Wasit Journal of Computer and Mathematics Science*, vol. 2, no. 1, pp. 93–111, 2023.

[12] U. I. Israilovich, M. Islombek, A. Akhadjon, and B. Oybek, "Operation of electric machines. Installation of electric machines and transformers," *Periodica Journal of Modern Philosophy, Social Sciences and Humanities*, vol. 19, pp. 25–27, 2023.

[13] H. Maghfiroh, M. Nizam, M. Anwar, and A. Ma'Arif, "Improved LQR control using PSO optimization and Kalman filter estimator," *IEEE Access*, vol. 10, pp. 18330–18337, 2022, doi: 10.1109/ACCESS.2022.3149951.

[14] E. S. Ghith and F. A. Tolba, "Real-time implementation of an enhanced PID controller based on ant lion optimizer for micro-robotics system," *Mathematical Modelling of Engineering Problems*, vol. 9, no. 4, pp. 1113–1122, 2022, doi: 10.18280/mmep.090430.

[15] W. Aribowo, S. Muslim, and B. Suprianto, "A hunger game search algorithm for economic load dispatch," *IAES International Journal of Artificial Intelligence*, vol. 11, no. 2, pp. 632–640, Jun. 2022, doi: 10.11591/ijai.v11.i2.pp632-640.

[16] D. Izci, "A novel improved atom search optimization algorithm for designing power system stabilizer," *Evolutionary Intelligence*, vol. 15, no. 3, pp. 2089–2103, Sep. 2022, doi: 10.1007/s12065-021-00615-9.

[17] S. Lim, Y. Yook, J. P. Heo, C. G. Im, K. H. Ryu, and S. W. Sung, "A new PID controller design using differential operator for the integrating process," *Computers and Chemical Engineering*, vol. 170, p. 108105, 2023, doi: 10.1016/j.compchemeng.2022.108105.

[18] M. Huba, D. Vrancic, and P. Bistak, “Series PID control with higher-order derivatives for processes approximated by IPDT models,” *IEEE Transactions on Automation Science and Engineering*, 2023, doi: 10.1109/TASE.2023.3296201.

[19] R. Benotsmane and G. Kovács, “Optimization of energy consumption of industrial robots using classical PID and MPC controllers,” *Energies*, vol. 16, no. 8, p. 3499, 2023, doi: 10.3390/en16083499.

[20] A. M. Abba, T. Karataev, S. Thomas, A. M. Ali, I. Yau, and S. A. Mikail, “Optimal PID controller tuning for DC motor speed control using smell agent optimization algorithm,” *FUOYE Journal of Engineering and Technology*, vol. 7, no. 1, pp. 23–27, 2022, doi: 10.46792/fuoyejet.v7i1.740.

[21] I. D. Fajuke and A. Raji, “Optimal tuning of PID controller for speed control of DC motor using equilibrium optimizer,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 30, no. 1, pp. 89–101, 2023, doi: 10.11591/ijeecs.v30.i1.pp89-101.

[22] A. I. Tajudin, M. A. D. Izani, A. A. A. Samat, S. Omar, and M. A. M. Idin, “Design a speed control for DC motor using an optimal PID controller implementation of ABC algorithm,” in *ICCSCE 2022 - Proceedings: 2022 12th IEEE International Conference on Control System, Computing and Engineering*, 2022, pp. 97–102, doi: 10.1109/ICCSCE54767.2022.9935644.

[23] A. Adarsh, A. Chawla, A. Singh, and B. Bhushan, “Performance analysis of DC motor using GWO and FPA,” in *2023 4th International Conference for Emerging Technology, INCET 2023*, 2023, pp. 1–5, doi: 10.1109/INCET57972.2023.10170189.

[24] M. Vesović, R. Jovanović, and N. Trišović, “Control of a DC motor using feedback linearization and gray wolf optimization algorithm,” *Advances in Mechanical Engineering*, vol. 14, no. 3, p. 168781322210853, Mar. 2022, doi: 10.1177/16878132221085324.

[25] M. Premkumar, P. Jangir, B. S. Kumar, M. A. Alqudah, and K. S. Nisar, “Multi-objective grey wolf optimization algorithm for solving real-world BLDC motor design problem,” *Computers, Materials & Continua*, vol. 70, no. 2, pp. 2435–2452, 2022, doi: 10.32604/cmc.2022.016488.

[26] A. Idir, L. Canale, S. A. Tadjer, and F. Chekired, “High order approximation of fractional PID controller based on grey wolf optimization for DC motor,” in *2022 IEEE International Conference on Environment and Electrical Engineering and 2022 IEEE Industrial and Commercial Power Systems Europe, EEEIC / I and CPS Europe 2022*, 2022, pp. 1–6, doi: 10.1109/EEEIC/ICPSEurope54979.2022.9854520.

[27] E. S. Ali, “Improved harmony search algorithm for speed control of DC series motor PV system,” *International Journal of Applied Sciences & Development*, vol. 1, pp. 75–82, 2022, doi: 10.37394/232029.2022.1.9.

[28] S. I. Khather, M. A. Ibrahim, and M. H. Ibrahim, “Dual fuzzy logic pid controller based regulating of DC motor speed control with optimization using harmony search algorithm,” *Eastern-European Journal of Enterprise Technologies*, vol. 124, no. 8, pp. 6–14, 2023, doi: 10.15587/1729-4061.2023.282830.

[29] D. D. Mishra, P. Padhi, A. A. Tripathy, S. Patnaik, and P. K. Sahoo, “Optimal tuning of fractional order PID controller using nelder-mead algorithm for DC motor speed control,” in *2023 International Conference in Advances in Power, Signal, and Information Technology, APSIT 2023*, 2023, pp. 373–378, doi: 10.1109/APSIT58554.2023.10201735.

[30] H. A. Shehadeh, “Chernobyl disaster optimizer (CDO): a novel meta-heuristic method for global optimization,” *Neural Computing and Applications*, vol. 35, no. 15, pp. 10733–10749, 2023, doi: 10.1007/s00521-023-08261-1.

[31] W. Aribowo, B. Suprianto, and J. Joko, “Improving neural network using a sine tree-seed algorithm for tuning motor DC,” *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 12, no. 2, pp. 1196–1204, Jun. 2021, doi: 10.11591/ijpeds.v12.i2.pp1196-1204.

[32] B. N. Kommula and V. R. Kota, “Direct instantaneous torque control of brushless DC motor using firefly algorithm based fractional order PID controller,” *Journal of King Saud University - Engineering Sciences*, vol. 32, no. 2, pp. 133–140, 2020, doi: 10.1016/j.jksues.2018.04.007.

[33] P. Barthelemy, J. Bertolotti, and D. S. Wiersma, “A Lévy flight for light,” *Nature*, vol. 453, no. 7194, pp. 495–498, May 2008, doi: 10.1038/nature06948.

[34] B. Hekimoglu, “Optimal tuning of fractional order PID controller for DC motor speed control via chaotic atom search optimization algorithm,” *IEEE Access*, vol. 7, pp. 38100–38114, 2019, doi: 10.1109/ACCESS.2019.2905961.

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