Metaheuristic-Based Photovoltaic Parameter Identification Using a Dynamic Elite Cooperative Artificial Circulatory System Algorithm

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INTRODUCTION & AIM

Accurate parameter estimation is essential for reliable photovoltaic (PV) modeling and maximum power point tracking. However, estimating the unknown parameters of the Single Diode Model (SDM) remains challenging because of its nonlinear and multimodal nature. This study proposes a Dynamic Elite Cooperative Artificial Circulatory System Algorithm (DEC-ACSA), which enhances the original ACSA through dynamic elite grouping, cooperative information exchange, elite-guided local search, and Gaussian-based perturbation. The proposed algorithm is evaluated on the RTC France benchmark and compared with the original ACSA.

METHOD

The PV parameter estimation problem is formulated using the Single Diode Model (SDM), where five unknown parameters are identified by minimizing the RMSE between measured and estimated currents.

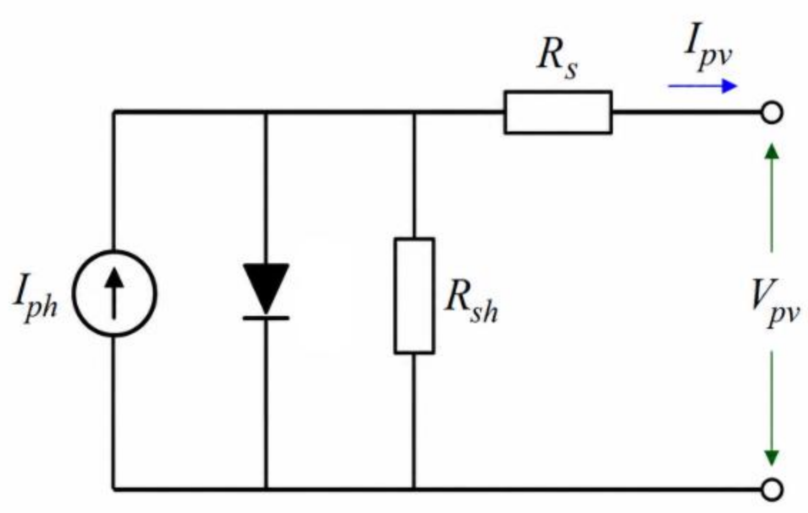

Figure 1: Single Diode Model (SDM) equivalent circuit used for photovoltaic parameter estimation

The Artificial Circulatory System Algorithm (ACSA) is a bio-inspired metaheuristic optimization algorithm that mimics the regulatory mechanisms of the human circulatory system to balance global exploration and local exploitation [1]. The proposed Dynamic Elite Cooperative Artificial Circulatory System Algorithm (DEC-ACSA) extends the original ACSA by incorporating dynamic elite cooperation mechanisms, including:

- ✓ **Dynamic elite grouping**
- ✓ **Cooperative information exchange**
- ✓ **Elite-guided local search**
- ✓ **Gaussian-based neural perturbation**

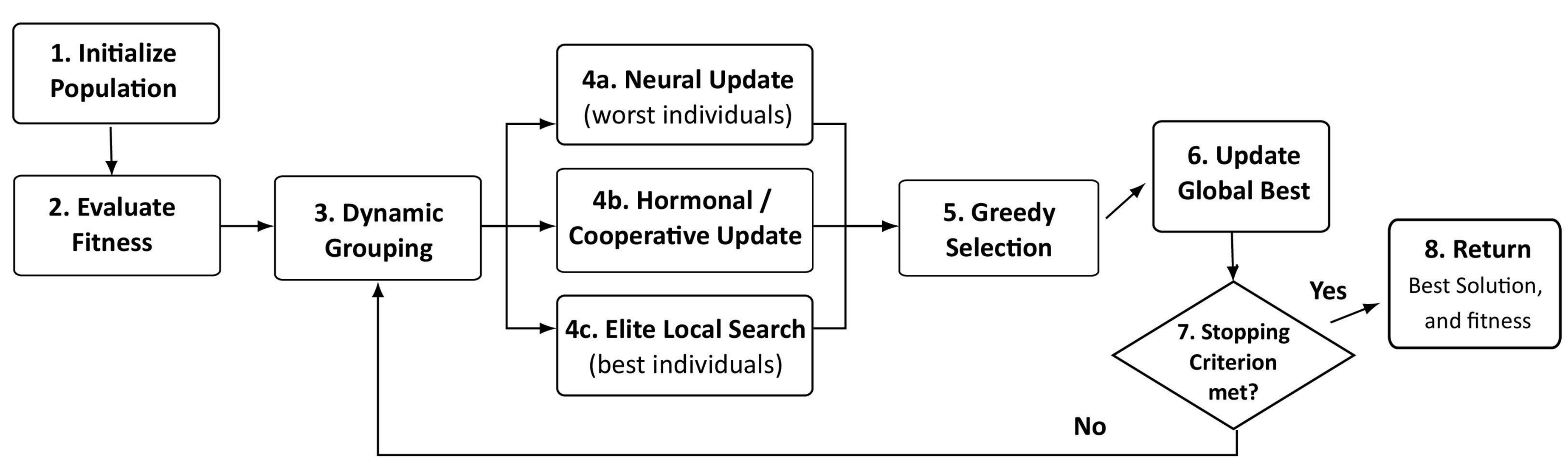

Figure 2: Flowchart of the proposed Dynamic Elite Cooperative Artificial Circulatory System Algorithm (DEC-ACSA)

RESULTS & DISCUSSION

The proposed DEC-ACSA consistently outperformed the original ACSA over 30 independent runs by achieving lower objective RMSE and improved optimization stability. As illustrated in Figure 3, DEC-ACSA exhibits faster convergence while maintaining consistent search behavior throughout the optimization process. Furthermore, the estimated I–V characteristics closely match the experimental measurements, and the corresponding residual analysis demonstrates significantly reduced current estimation errors. These findings confirm that dynamic elite cooperation effectively enhances both convergence efficiency and parameter estimation accuracy.

Table 1. Statistical comparison of objective RMSE over 30 independent runs.

Algorithm	Best	Mean	Worst	Std.
ACSA	5.2832×10^{-3}	3.6079×10^{-2}	1.7202×10^{-1}	3.2816×10^{-2}
DEC-ACSA	9.9952×10^{-4}	2.0649×10^{-3}	3.6343×10^{-3}	7.4737×10^{-4}

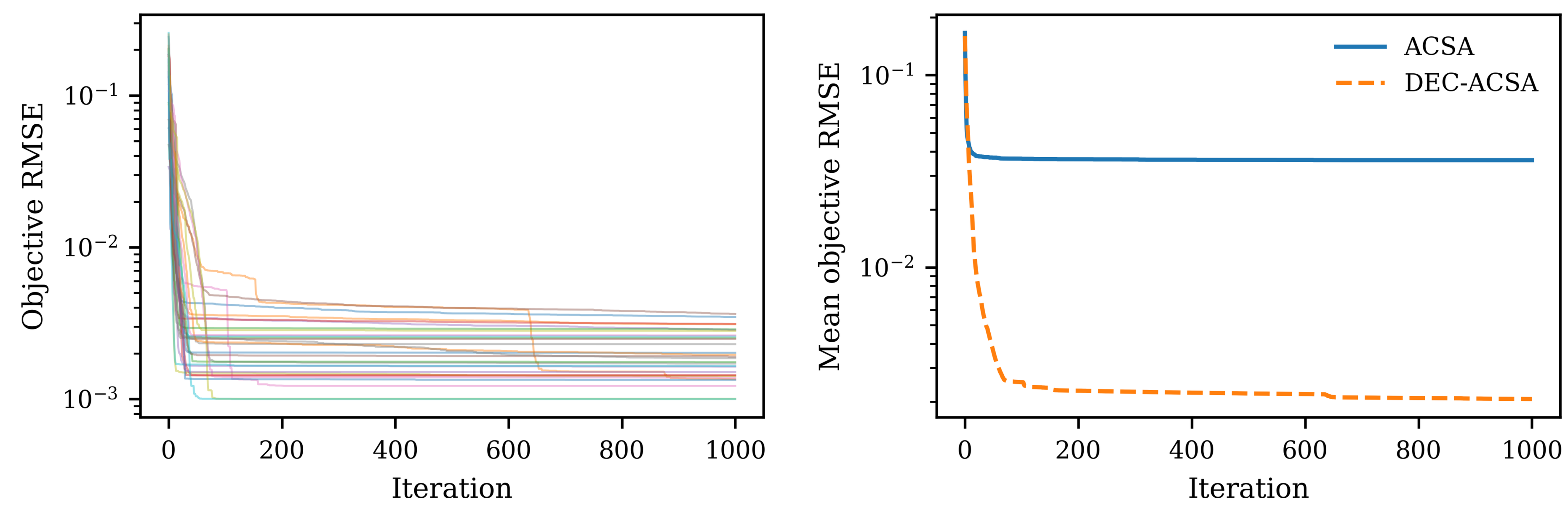

Figure 3: Convergence characteristics of the proposed DEC-ACSA. (a) Objective RMSE obtained in 30 independent runs. (b) Mean convergence curves of ACSA and DEC-ACSA

Table 2. Best SDM parameters obtained by ACSA and DEC-ACSA.

Algorithm	I_{ph} (A)	I_s (A)	R_{sh} (Ω)	R_s (Ω)	n
ACSA	7.5279×10^{-1}	1.9861×10^{-7}	7.2880×10^{1}	3.7212×10^{-2}	1.4341
DEC-ACSA	7.6073×10^{-1}	3.5161×10^{-7}	5.6580×10^{1}	3.6049×10^{-2}	1.4898

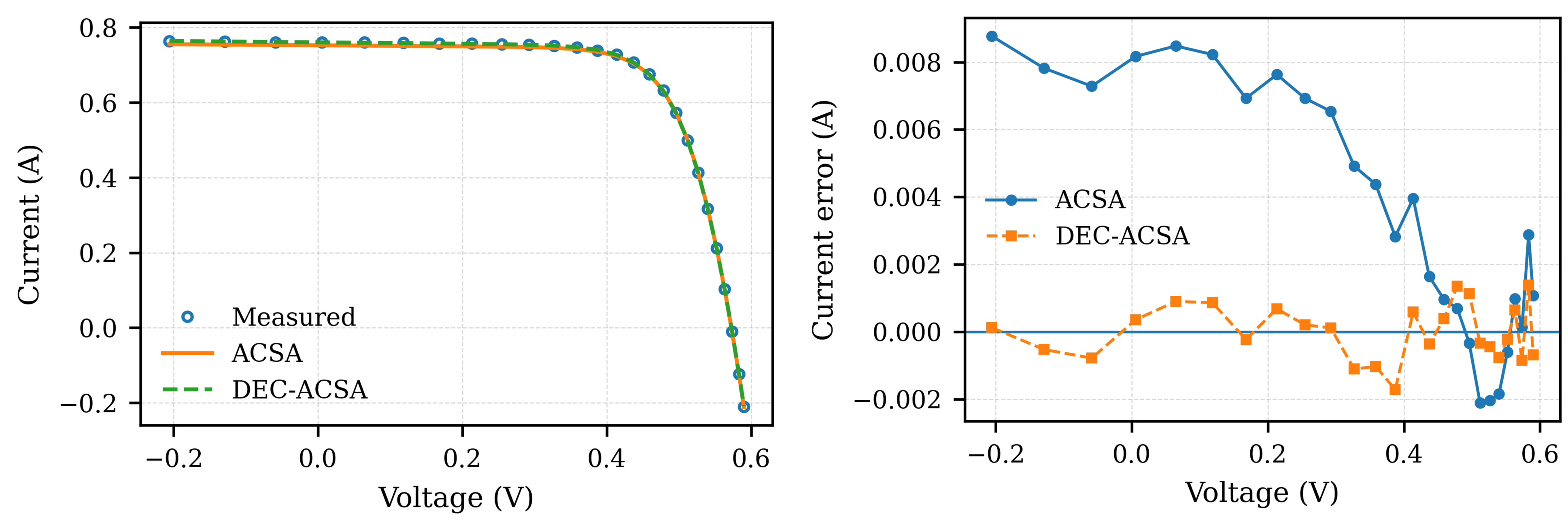

Figure 4: Comparison of measured and estimated electrical characteristics. (a) Experimental and estimated I–V curves. (b) Current estimation errors obtained by ACSA and DEC-ACSA

CONCLUSIONS

This study introduced a Dynamic Elite Cooperative Artificial Circulatory System Algorithm (DEC-ACSA) for photovoltaic parameter identification based on the Single Diode Model. By integrating dynamic elite grouping and cooperative information exchange into the original ACSA framework, the proposed method achieved faster convergence, lower estimation errors, and improved robustness. The experimental results demonstrate that DEC-ACSA provides an effective and reliable optimization approach for accurate photovoltaic model parameter estimation.

FUTURE WORK

Future work will focus on extending the proposed approach to more complex photovoltaic models, including the Double Diode Model, and evaluating its performance on different PV modules under various operating conditions. Additional studies will also investigate the applicability of the proposed cooperative strategy to other engineering optimization problems.

REFERENCES

[1] Özcan, N., Utku, S., & Berber, T. (2024). Artificial Circulation System Algorithm: A novel Bio-Inspired Algorithm. Computer Modeling in Engineering & Sciences, 142(1), 635–663. https://doi.org/10.32604/cmes.2024.055860