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Editorial

Symmetry in Process Optimization

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Editorial

This Special Issue, 'Symmetry in Process Optimization', brings together recent theoretical and applied studies demonstrating how the principles of symmetry can be systematically exploited to enhance optimization methods, improve computational efficiency, and increase robustness across diverse scientific and engineering domains. In complex optimization problems—characterized by combinatorial explosion, structural constraints, and heterogeneous data—symmetry-aware modeling provides a principled mechanism for reducing redundancy and improving tractability [1–13].

The relevance of symmetry in scheduling and production systems is particularly evident. The contributions included in this Special Issue address constrained parallel machine scheduling [1], while related research in the broader literature demonstrates how metaheuristic frameworks—such as modified Harris Hawks optimization [11] and artificial bee colony algorithms [12]—can effectively exploit structural symmetries in machine scheduling. Arc-flow formulations further show how symmetry can be embedded in exact optimization models for uniform parallel machine problems [13]. Collectively, these works reinforce the importance of symmetry in both heuristic and exact scheduling methodologies.

In manufacturing and additive production systems, symmetry plays a critical role in design, process planning, and surface optimization. The studies included in this Special Issue investigate machining symmetry [5] and topology optimization combined with part orientation strategies in additive manufacturing [6]. These approaches align with broader investigations into symmetry applications in metal additive manufacturing processes [14] and medical modeling via additive manufacturing [15], where geometric symmetry directly influences mechanical performance and functional accuracy.

Machine learning and computer vision represent another prominent axis of symmetry-aware optimization. Within this Special Issue, symmetry-enhanced few-shot segmentation [2] and hardware-optimized real-time image dehazing systems [9] demonstrate how symmetry can improve model consistency and efficiency. Complementary studies in the literature further highlight the importance of symmetric feature representations in semantic segmentation [16], infrastructure defect detection [17], generative adversarial dehazing networks [18], and asymmetry-guided object detection frameworks [19]. These works collectively illustrate how embedding symmetry into deep architectures improves generalization and robustness.

Control systems and dynamical modeling also benefit from the principles of symmetry. Fractional-order control strategies [7] and symmetry-optimized dynamical beam analysis [8] demonstrate how symmetric system modeling enhances stability and analytical tractability. Related research in permanent magnet synchronous motor control shows how symmetry-aware sliding mode control [20] and uncertainty/disturbance estimation strategies [21] improve precision and robustness in servo systems.

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Finally, symmetry in decision-making and reconstruction frameworks can be addressed using fuzzy matrix optimization models [10] and symmetry-based 3D reconstruction using genetic algorithms [3], further emphasizing the versatility of the principles of symmetry in computational intelligence and engineering design.

Together, the contributions included in this Special Issue and the related works cited above demonstrate that symmetry is not merely a mathematical abstraction, but a unifying structural principle that enhances optimization across scheduling, manufacturing, machine learning, control, and decision-making systems. By bridging theoretical foundations with real-world applications, this Special Issue highlights the transformative potential of symmetry-aware optimization in addressing contemporary scientific and industrial challenges.

We anticipate that this Special Issue will serve as a valuable reference for researchers and practitioners and will stimulate continued interdisciplinary research at the intersection of symmetry theory and process optimization.

Conflicts of Interest: The authors declare no conflicts of interest.

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