



Chapter 11

Particle Swarm Optimization in Biomedical Technologies: Innovations, Challenges, and Opportunities

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ABSTRACT

This chapter explores particle swarm optimization (PSO) in the rapidly evolving landscape of biomedical technologies. The study begins by introducing the fundamental principles of PSO, emphasizing its advantages in addressing complex optimization problems common in biomedical applications. The authors delve into innovative uses of PSO in various biomedical fields, including image enhancement, data clustering, and drug development, highlighting how PSO contributes to more accurate diagnoses, efficient treatment plans, and streamlined research methodologies. Significantly, this chapter identifies emerging opportunities where PSO can be further leveraged, particularly in personalized medicine and predictive health analytics, suggesting a roadmap for future research and development. By combining theoretical insights with practical examples, this work aims to provide a comprehensive overview of PSO's role in advancing biomedical technologies, offering valuable perspectives for researchers, practitioners, and policymakers in the field.

INTRODUCTION

Swarm intelligence (SI) is a population-based optimization approach, which is a sub-domain of soft computing techniques (Ab Wahab et al., 2015; Hamami & Ismail, 2022; Peška et al., 2019). It typi-

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cally imitates the social behaviors of various animals observed in nature to solve problems. In quadratic equations, SI plays a crucial role in optimizing these equations with maximum accuracy and efficiency. One specific form of SI is Particle Swarm Optimization (PSO), which mimics the social behavior of birds while foraging (Huang et al., 2012; Xue & Shen, 2020). This article utilizes the expanded Kaptur's entropy criteria approach as the fitness function to optimize two threshold values using the basic PSO methodology.

In computer vision, edge detection is a critical task and remains an active research area due to its frequent use as a preliminary step in extracting information from images. Edge detection plays a pivotal role in object identification, image segmentation, and understanding the structure of an image. The edges in an image provide valuable information about the frontiers or boundaries of objects within a computer vision application (Garcia, 2020; Haji et al., 2012; Islam et al., 2016; Pramanik & Bag, 2018; Sharma et al., 2014). These edges are formed due to changes in object characteristics such as geometry, shape, size, light intensity, and reflection. In gray-level images, an edge is defined as a line that separates two areas with different grey levels, which is a discontinuity in image intensity or its first derivative. There are two main types of image intensity discontinuities: step and line discontinuities. Step discontinuities are caused by rapid changes in image intensity, while line discontinuities are abrupt changes in intensity that return to their initial level after a certain distance (Azarbad et al., 2010; Gao et al., 2010; Ye et al., 2010). However, due to factors like smoothing from sensing equipment, low-frequency components in images, and external noise, these discontinuities are often not visible in real photographs, leading to the formation of ramp edges from step intensity changes and roof edges from line intensity changes.

Efficient image processing techniques, including clustering, are essential for accurate pattern recognition (Cheng et al., 2001; Deeparani & Sudhakar, 2021; Mishra et al., 2023). However, many existing clustering methods depend on human intervention and may not yield correct results when visual input is distorted. One of the most significant challenges in automation across various social sectors is the application of machine vision. This research specifically explores the use of machine vision in autonomous vehicles, focusing on identifying other road users (including autonomous vehicles), road infrastructure, and road markings (Liao et al., 2011; Nelson Jayakumar & Venkatesh, 2014; Wu et al., 2012).

MAIN FOCUS OF THE CHAPTER

This chapter explores the burgeoning role of technology in healthcare (Hauwaert et al., 2024; Martin & Alarcón-Urbistondo, 2024; Silva et al., 2024), highlighting various technological innovations such as advanced biomedical imaging, LIDAR in diagnostics, and optimization algorithms in treatment planning, which collectively enhance health literacy and patient care (Almeida, 2024; Aminabee, 2024). It aims to address pivotal questions around the integration of these technologies in medical practice, examining their impact on diagnostics, treatment efficacy, and patient outcomes (Bi & Uludag, 2024; Miller et al., 2024; Thapliyal et al., 2024). By offering a unique perspective, this chapter contributes to the field through innovative research on Particle Swarm Optimization (PSO) and its applications in medical image processing, alongside novel theoretical approaches in LIDAR data interpretation for patient diagnostics. It underscores the chapter's relevance in current healthcare trends (Lobo et al., 2024; Pramanik, 2024; Roy & Ashmika, 2024), particularly in the digitalization of healthcare services and the growing importance of data-driven decision-making in clinical settings (Garcia et al., 2024; Tariq, 2024). This positions the

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