

Research on fuzzy clustering algorithm using hedge algebra theory and WOA optimization algorithm

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Abstract: This study proposes a novel fuzzy clustering algorithm that integrates hedge algebra theory with the Whale Optimization Algorithm (WOA) to address limitations in conventional fuzzy C-means (FCM) methods, particularly sensitivity to initialization and convergence to local optima. Hedge algebra theory is employed to model linguistic hedges and quantify semantic uncertainty, enabling a more nuanced representation of data membership degrees. The WOA, inspired by the social behavior of humpback whales, is utilized to optimize the cluster centers and membership matrix, enhancing global search capability and convergence speed. Experimental evaluations on benchmark datasets demonstrate that the proposed algorithm achieves superior clustering accuracy, stability, and robustness compared to standard FCM and other metaheuristic-based clustering approaches. The integration of hedge algebra provides a theoretical framework for handling vague information, while WOA ensures efficient optimization. Results indicate significant improvements in partition entropy and clustering validity indices, validating the effectiveness of combining soft computing techniques for complex data analysis. This work contributes to advancing fuzzy clustering methodologies with potential applications in pattern recognition and data mining.

Keywords: fuzzy clustering, hedge algebra, WOA optimization, fuzzy C-means