Hierarchical Heterogeneous Particle Swarm Optimization: Algorithms, Developments and Applications

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Abstract: Particle swarm optimization (PSO) has recently been extended in several directions in order to improve its global searching ability. In this dissertation, I propose Hierarchical Heterogeneous Particle Swarm Optimization (HHPSO), in which heterogeneous behaviors of particles are enforced through interactions among hierarchically structured particles. Two algorithms have been developed and studied: multi-layer HHPSO (ml-HHPSO) and multi-group HHPSO (mg-HHPSO). After measuring the algorithm performance on a set of benchmark functions, the results demonstrated that both ml-HHPSO and mg-HHPSO performed well on all testing problems and significantly outperformed SPSO and HPSO in terms of solution accuracy, convergence speed, diversity maintenance and algorithm scalability. By exploring three important parameters involved in the HHPSO algorithm, we identified the optimal parameter settings that led to better algorithm performance at low computational cost. In the second part of my dissertation, I studied HHPSO’s applications to problems of feature selection and brain pattern recognition. I first integrated HHPSO and a support vector machine (SVM) to develop a novel feature selection approach to solve high dimensional and multi-objective feature selection problems. The new feature selection method is developed for multi-voxel pattern analysis (MVPA), which aims to identify efficient brain response patterns for pattern classification problems. Second, the proposed HHPSO-SVM feature selection algorithm was implemented twice in a new feature interaction detection framework (FIDF) to extract informative voxels and connectivity patterns, which distinguish different cognitive states. The effectiveness of the proposed approach was examined for the Haxby’s dataset of object-level representations. The computational results demonstrated higher classification accuracy by the extracted response patterns, compared to state-of-the-art feature selection algorithms, such as forward selection and backward selection.