Multi-objective Quantum-inspired Evolutionary Algorithm (MQEA) and Multi-objective Footstep Planning for Humanoid Robots

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Abstract:

This tutorial firstly introduces quantum-inspired evolutionary algorithm (QEA), which is based on the concept and principles of quantum computing, such as a quantum bit and superposition of states. Like other evolutionary algorithms, QEA is also characterized by the representation of the individual, the evaluation function, and the population dynamics. However, instead of binary, numeric, or symbolic representation, QEA uses a Q-bit, defined as the smallest unit of information, for the probabilistic representation and a Q-bit individual as a string of Q-bits. A Q-gate is introduced as a variation operator to drive the individuals toward better solutions. QEA performs excellently, even with a small population, without premature convergence with exploration and exploitation ability.

As a second topic, this tutorial introduces multi-objective quantum-inspired evolutionary algorithm (MQEA) which is based on QEA to
improve the proximity to Pareto-optimal front and diversity of nondominated solutions for either multiobjective combinatorial optimization problems or numerical optimization problems. It has an advantage to maintain elitism by storing nondominated solutions of archive externally. Global random migration of nondominated solutions in the archive is adopted to preserve the diversity of solutions of each sub-population. Cooperative coevolutionary concept of MQEA based on parallel structure has robust search ability on more complex and higher-dimensional objective problems. Experimental results on multiobjective 0/1 knapsack problems and DTLZ problems show the effectiveness of the proposed MQEA from the viewpoint of the proximity to the Pareto-optimal set and the spread of nondominated set, measured by four performance metrics such as attainment surface, size of the dominated space, coverage of two sets and diversity metric.

As a last topic, this tutorial presents a novel evolutionary multi-objective footstep planner for humanoid robots using MQEA. Firstly, recent progress and development of small-sized humanoid robot HanSaRam (HSR) is introduced, which has been in continual development and research by the Robot Intelligence Technology (RIT) Laboratory, KAIST since 2000. A footstep planner using univector field navigation method is presented to provide a command state (CS) which is to be an input of modifiable walking pattern generator (MWPG), developed at RIT Lab., at each footstep. Then MWPG generates corresponding trajectories of every leg joint of the humanoid robot at each footstep to follow the CS. MQEA is employed to optimize univector fields satisfying multiple objectives in navigation. To select a preferred one out of various nondominated solutions obtained by MQEA, preference-based solution selection algorithm (PSSA) is used. The algorithm is based on fuzzy measure and fuzzy integral. The effectiveness of the proposed evolutionary multi-objective footstep planner is demonstrated through experiments with the small-sized humanoid robot, HanSaRam-VIII (HSR-VIII).