Multiobjective Quantum-inspired Evolutionary Algorithm and Preference-based Solution Selection Algorithm (MQEA and PSSA)

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Outline:

This tutorial consists of five parts; QEA (quantum-inspired evolutionary algorithm), MQEA (multiobjective quantum-inspired evolutionary algorithm), PSSA (preference-based solution selection algorithm), MQEA-PS (multiobjective quantum-inspired evolutionary algorithm with preference-based selection), and the real world applications including gaze control and footstep planning of the small-sized humanoid robot HanSaRam (HSR) and multicriteria decision making of the robotic fish Fibo, both developed in the RIT (Robot Intelligence Technology) Lab., KAIST.

This tutorial firstly introduces 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. Instead of binary, numeric, or symbolic representation, however, QEA uses a Q-bit, defined as a smallest unit of information, for the probabilistic representation and a Q-bit individual as a string of Q-bits. A Q-gate is employed as a variation operator to drive the individuals toward better solutions. QEA performs excellently with exploration and exploitation ability, even with a small population, without premature convergence.

As a second topic, this tutorial introduces 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.

Since multiobjective evolutionary algorithms (MOEAs) including MQEA provide a set of nondominated solutions, decision making of selecting a preferred one out of them is required in real applications. For this purpose, this tutorial introduces PSSA by which user can select a preferred one out of nondominated solutions obtained by any one of MOEAs. The PSSA, which is a kind of multiple criteria decision making (MCDM) algorithm, represents user’s preference to multiple objectives or criteria as a degree of consideration by fuzzy measure and globally evaluates obtained solutions by fuzzy integral. The PSSA is also employed in each and every generation of evolutionary process to design MQEA-PS. Computer simulation and experiment results show that the user’s preference is properly reflected in the selected solution. Moreover, MQEA-PS shows improved performance for the DTLZ problems and fuzzy path planner optimization problem compared to MQEA with dominance-based selection and other MOEAs like NSGA-II and MOPBIL.

As a last topic, this tutorial presents a novel evolutionary multi-objective footstep planner for humanoid robots using MQEA and PSSA. Firstly, recent progress and development of the small-sized humanoid robot HanSaRam (HSR) is introduced, which has been in continual development and research by the RIT Lab., 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), at each footstep. Then, MWPG generates corresponding trajectories of every leg joint of the humanoid robot at each footstep to follow the CS in real-time. 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, PSSA is used. The effectiveness of the proposed evolutionary multi-objective footstep planner is demonstrated through experiments with the HSR-VIII. Also, the PSSA is applied to the gaze control of HSR-VIII and the multicriteria decision making the robotic fish Fibo, developed in the RIT Lab. in 2010, in a sensor node environment.

Expected enrolment:

An ordinary seminar room with a beam projector is enough.

Biography:

Jong-Hwan Kim received his B.S., M.S. and Ph.D. degrees in Electronics Engineering from Seoul National University, Korea, in 1981, 1983 and 1987, respectively. Since 1988, he has been with the Department of Electrical Engineering at KAIST and is currently KT Chair Professor. He was Head of Robotics Program, KAIST for 2004-2006. He is Adjunct Professor of Griffith University, Australia and Honorary Professor of De La Salle University, the Philippines. Dr. Kim is Director for both of the National Robotics Research Center for Robot Intelligence Technology and the National Research Lab for Cognitive Humanoid Robots. His research interests include computational intelligence and ubiquitous and genetic robotics. Dr. Kim has authored 5 books and 3 edited books, 2 journal special issues and around 300 refereed papers in technical journals and conference proceedings. He currently serves as an Associate Editor of the *IEEE T. on Evolutionary Computation* and the *IEEE Computational Intelligence Magazine*. Dr. Kim was one of the co-founders of the Int'l Conf. on *Simulated Evolution and Learning* in 1996. He was General Chair for the *IEEE Congress on Evolutionary Computation*, Korea, 2001 and General Chair for the *IEEE Int'l Symp. on Computational Intelligence in Robotics and Automation*, Korea, 2009. He has been on the program committees and advisory boards of more than 100 int'l conferences. Dr. Kim has delivered over 180 invited talks, keynote speeches and tutorials on computational intelligence and robotics in 24 countries. His name was included in the *Barons 500 Leaders for the New Century* in 2000 as *the Father of Robot Football*. He is the Founder of FIRA and IROC and is currently serving them as President. Dr. Kim was the recipient of the science and technology award from the President of Republic of Korea in 1997 and has been elevated to 2009 IEEE Fellow.

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