Probability Collectives for Solving Truss Structure Problems

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Abstract:

The growing complexity and uncertainty in the problem domain made the system too difficult to treat in a centralized way. This motivated researchers to resort to distributed approach in which the entire system is decomposed into subsystems which can be viewed as a collective or a group of learning agents or a Multi Agent System (MAS). An emerging Artificial Intelligence (AI) tool in the Collective Intelligence (COIN) framework for modeling and controlling distributed MAS referred to as Probability Collectives (PC) was first proposed by David Wolpert in 1999 in a technical report presented to NASA. It is inspired from the sociophysics viewpoint with deep connections to Game Theory, Statistical Physics and Optimization. The method of PC theory is an efficient way of sampling the joint probability space, converting the problem into convex space of probability distribution. PC considers the variables in the system as individual agents of a game being played iteratively. Unlike other stochastic approaches such as Genetic Algorithms, Particle Swarm Optimization, Simulated Annealing, etc. rather than deciding over the agents' moves associated with its strategy set, PC allocates certain probability values for selecting each of the agent's moves which directly incorporates uncertainty. In PC, every agent iteratively updates its independent probability distribution to select a particular action out of its strategy set which optimizes its local goal and also optimizes the global goal or system objective. This process continues and reaches Nash equilibrium at which no further increase in the reward is possible for any agent by changing its actions further. The key characteristics of the PC methodology such as its ability to accommodate discrete, continuous and mixed variables as well as irregular and noisy functions, tolerance to subsystem/agent failure, ability to provide sensitivity information and ability to handle uncertainty in terms of probability, use of homotopy function to make the solution jump out of possible local minima, ability to avoid the tragedy of commons, high scalability, ability to achieve unique Nash Equilibrium, etc. make it a competitive choice over other algorithms for optimizing collectives.

PC approach has been successfully applied in variegated areas such as, fleet assignment problem, university course scheduling problem and Multiple Travelling Salesman Problem. It was also tested on various benchmark test problems including circle packing problem. Moreover, the potential of PC has been successfully demonstrated solving real world problems such as sensor network coverage problem and airplane collision avoidance problem. The potential of PC was also demonstrated solving discrete two dimensional 45-bar truss structure problem; however, the ability of PC approach solving discrete three dimensional as well as continuous truss structure problems has not been tested. The present work intends to demonstrate the potential of the PC approach solving discrete three dimensional 25-bar and 72-bar truss structure problems, and a continuous two dimensional 15-bar truss structure problem. In applying PC solving these problems, the truss members are viewed as autonomous agents which select their individual cross-sectional areas to collectively minimize the weight of the truss structure.