

Parameter estimation for Multivariate Gamma distribution with Particle Swarm Optimization based on Taguchi method

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Abstract

The Multivariate Gamma distribution is widely utilized in stochastic modeling, hydrology, reliability analysis, and actuarial sciences. Despite its broad applicability, efficient parameter estimation remains a challenge, as the maximum likelihood estimators lack closed-form solutions. Metaheuristic optimization techniques, particularly Particle Swarm Optimization (PSO), have been frequently employed to address this issue. However, the performance of PSO is highly sensitive to parameter settings, and in the absence of a structured approach, parameter tuning often relies on time-consuming trial-and-error methods. This study employs the Taguchi experimental design to systematically determine the optimal parameter configuration for PSO in estimating the parameters of the Multivariate Gamma distribution. By providing a structured framework for parameter tuning, the proposed approach reduces dependence on heuristic or arbitrary selection strategies. The performance of the Taguchi-optimized PSO is evaluated based on solution quality, measured using the deficiency (DEF) criterion, and computation time. The results indicate that the Taguchi method offers an efficient and replicable solution for PSO parameter tuning, eliminating the need for conventional trial-and-error methods. By structuring the tuning process, this approach enhances both the reliability and reproducibility of PSO-based estimation, making it adaptable to a range of similar optimization tasks. Future studies may explore comparative analyses with other parameter tuning strategies, extend the application to alternative metaheuristic algorithms, or adapt the methodology to optimization challenges in machine learning and data science contexts.

Keywords: Maximum Likelihood; Multivariate Gamma Distribution; Parameter Estimation; Parameter Tuning; Particle Swarm Optimization; Taguchi Experimental Design