Thesis: Novel Hybrid Resampling Algorithms for Parallel/Distributed Particle Filters

Abstract: Particle filters have been widely used in estimating the states of dynamical systems by using stochastic sampling techniques. The parallel/distributed particle filters were introduced to improve the performance of sequential particle filters with multiple processing units (PUs). In this study, we propose novel hybrid resampling algorithms to dynamically adjust the intervals between the centralized resampling steps and the decentralized resampling steps based on the measured system convergence. We analyze the computation time, the communication time, and the speedup factors of parallel/distributed particle filters with various resampling algorithms, state sizes, system complexities, numbers of processing units, and model dimensions. The experimental results indicate that the decentralized resampling achieves the highest speedup factors due to the local transfer of particles, the centralized resampling always has the lowest speedup factors because of the global transfer of particles, and the hybrid resampling attains the speedup factors between. Moreover, we define the complexity-state ratio, as the ratio between the system complexity and the system state size to study how it impacts the speedup factor. The experiments show that the higher complexity-state ratio results in the increase of the speedup factors. This is one of the earliest attempts to analyze and compare the performance of parallel/distributed particle filters with different resampling algorithms. The analysis can provide potential solutions for further performance improvements and guide the appropriate selection of the resampling algorithms. Meanwhile, we formalize various hybrid resampling algorithms to be a generic resampling algorithm and proved it to be uniformly convergent. The proof provides a solid theoretical foundation for their wide adoptions in parallel/distributed particle filters.

Committee:

- Professor Feng Gu, mentor, College of Staten Island
- Professor Liang Zhao, Lehman College
- Professor Shuqun Zhang, College of Staten Island

Outside Member:

- Professor Wei Zhong, University of South Carolina, Upstate