



Hybrid Particle Filter Data Assimilation Technique

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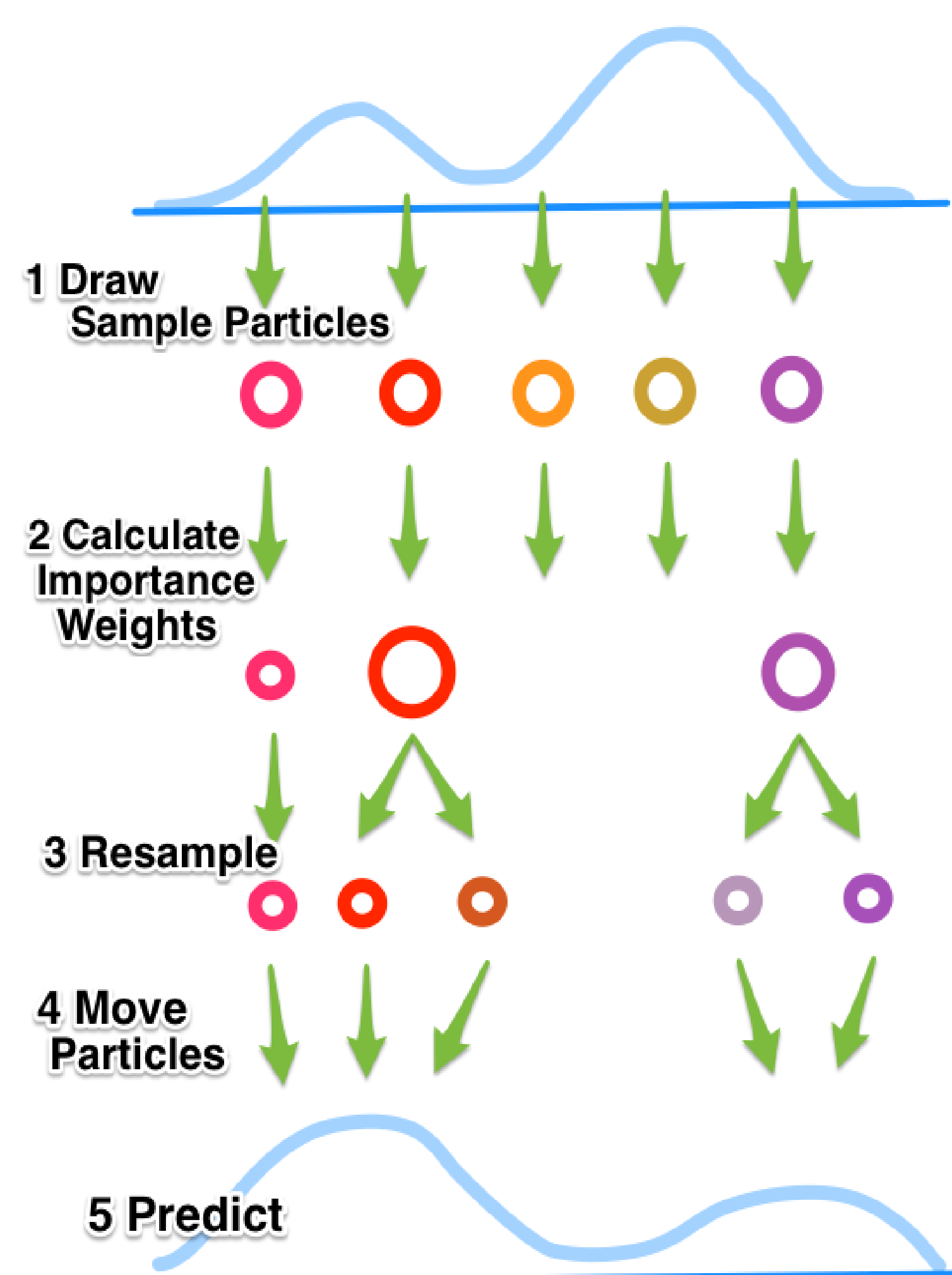
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Abstract

Data assimilation is a process by which observational data are optimally incorporated into a computational model of a real system. Data assimilation techniques have been successfully applied to real-world problems, including weather prediction, image tracking, and finance. However, applications to large-scale problems remain challenging, particularly with respect to efficiency and accuracy. The particle filter method is a data assimilation algorithm used for solving nonlinear forecasting problems with non-Gaussian errors. The goal of our research is to identify the limitations of the particle filter, and to develop algorithms to overcome these limitations. We implemented and tested the classic particle filter in 1 and 3 dimensions, as well as a hybrid particle filter using the particle swarm optimization (PSO) algorithm. Initial test results on the PF-PSO indicate that the algorithm does alleviate some limitations of the particle filter, but does so at the great cost of efficiency and accuracy. We are currently conducting tests on the pure PSO algorithm in order to better adjust the algorithm to fit the needs of the particle filter.

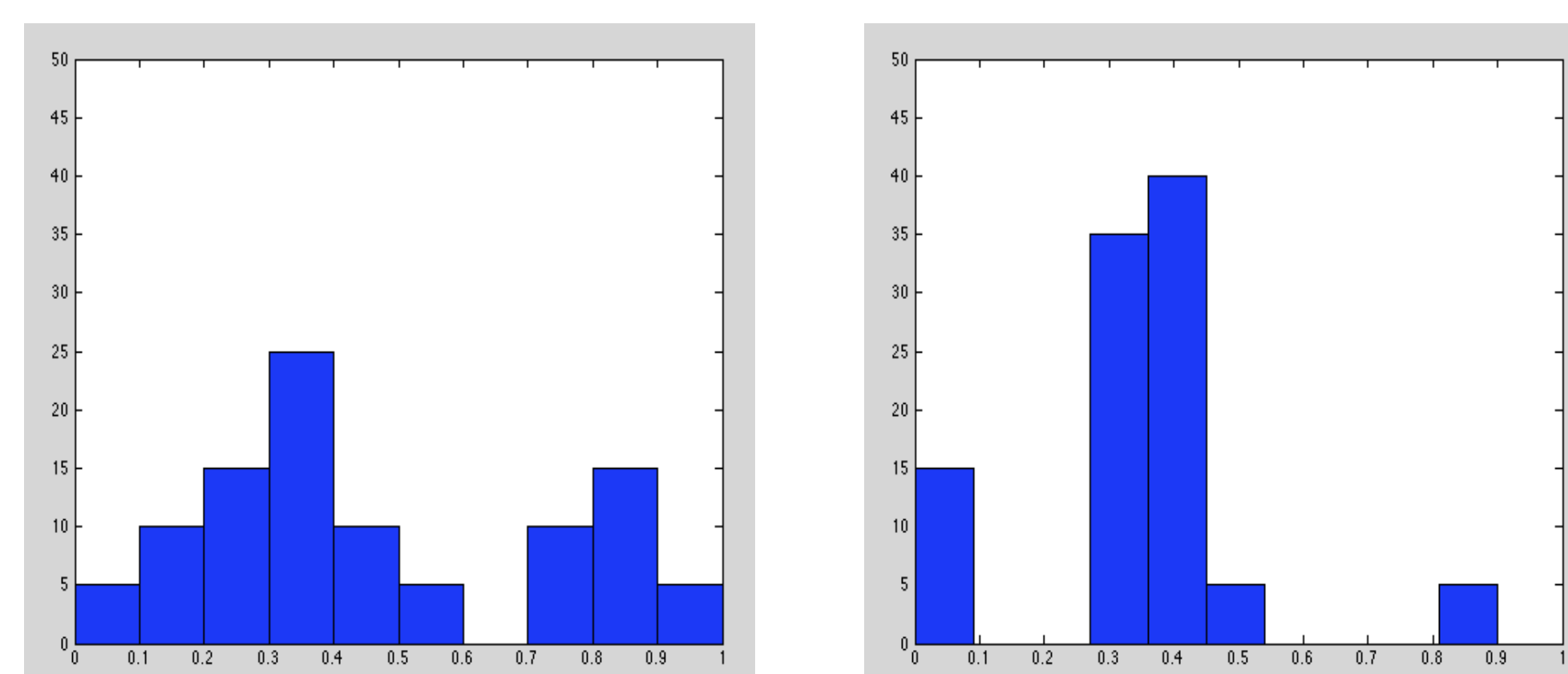
Particle Filter

The particle filter is a data assimilation algorithm which uses Bayesian estimation to approximate probability density functions (pdf) representing the likely state-space at a given time step.



Particle Degeneration

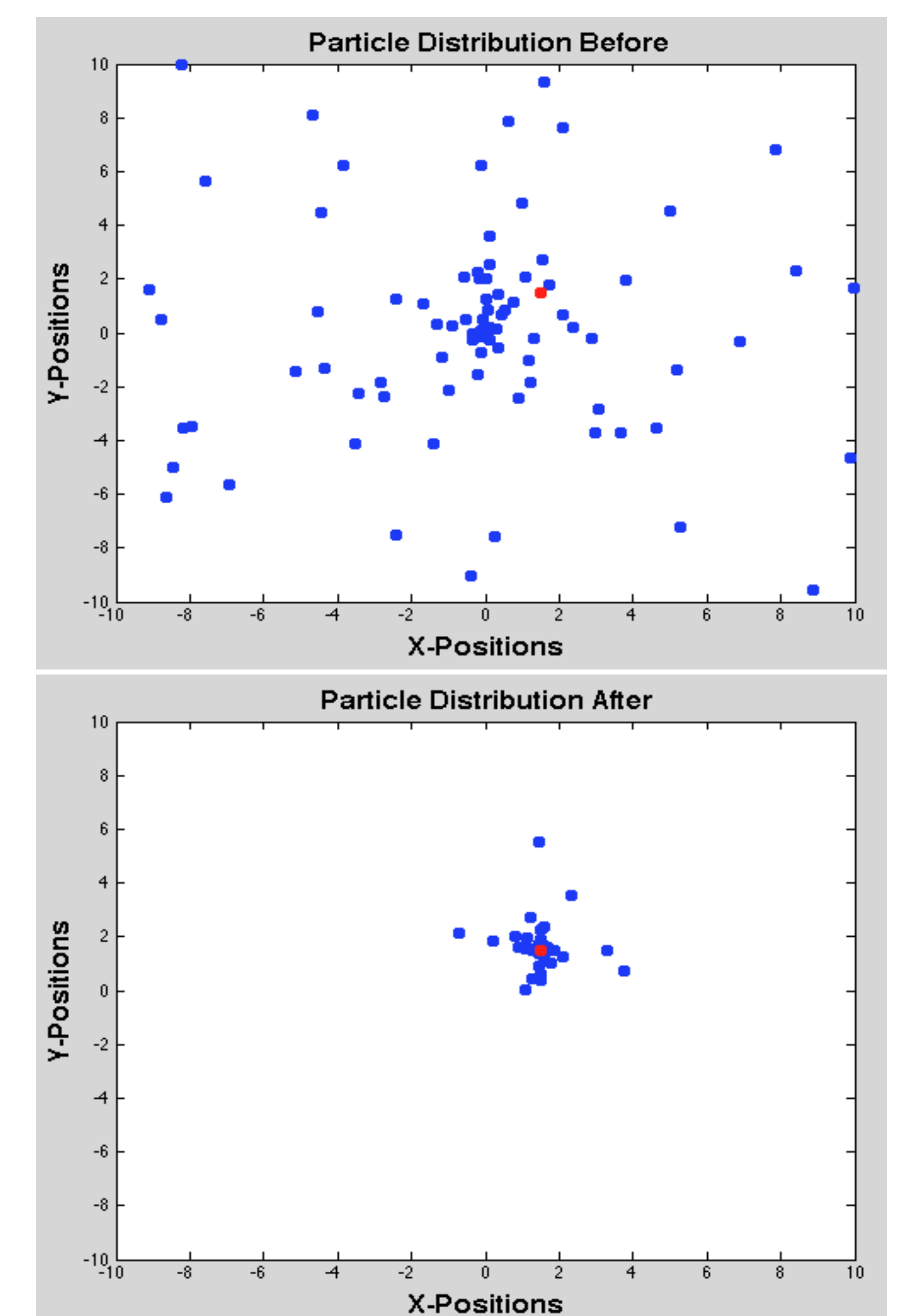
Particle degeneration is a side effect of the particle filter's weight calculation step. It occurs when the normalized particle weights are concentrated over a small number of high-weight particles, while the remaining low-weight particles are practically obsolete (right).



Resampling the particles at each time step reintroduces low-weight particles into the system and reduces the risk of degeneration, but is extremely inefficient. In order to combat this inefficiency while still addressing the problem of degeneration, we introduce an auxiliary algorithm, Particle Swarm Optimization, to replace the resampling step.

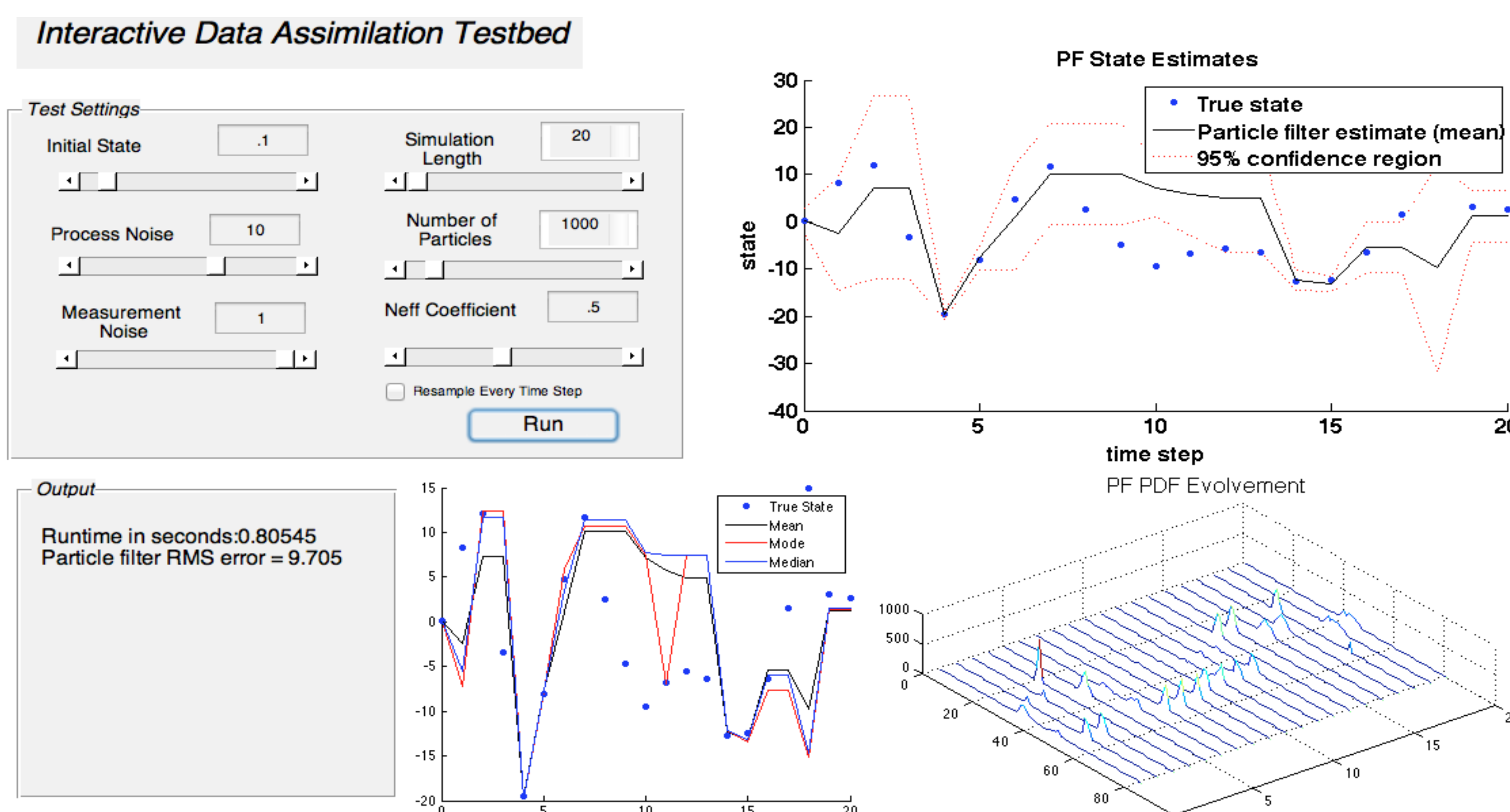
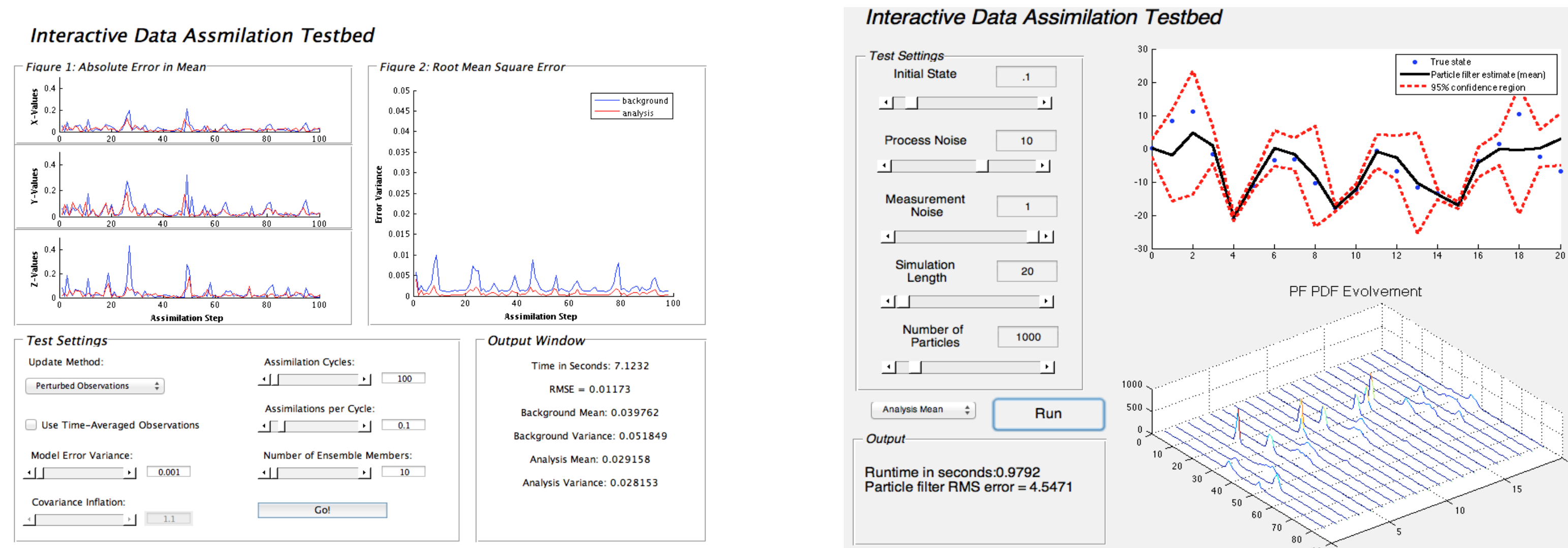
Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO), is an optimization technique based on naturally occurring swarm behavior. The algorithm causes particles to converge on the observation point, as seen below:



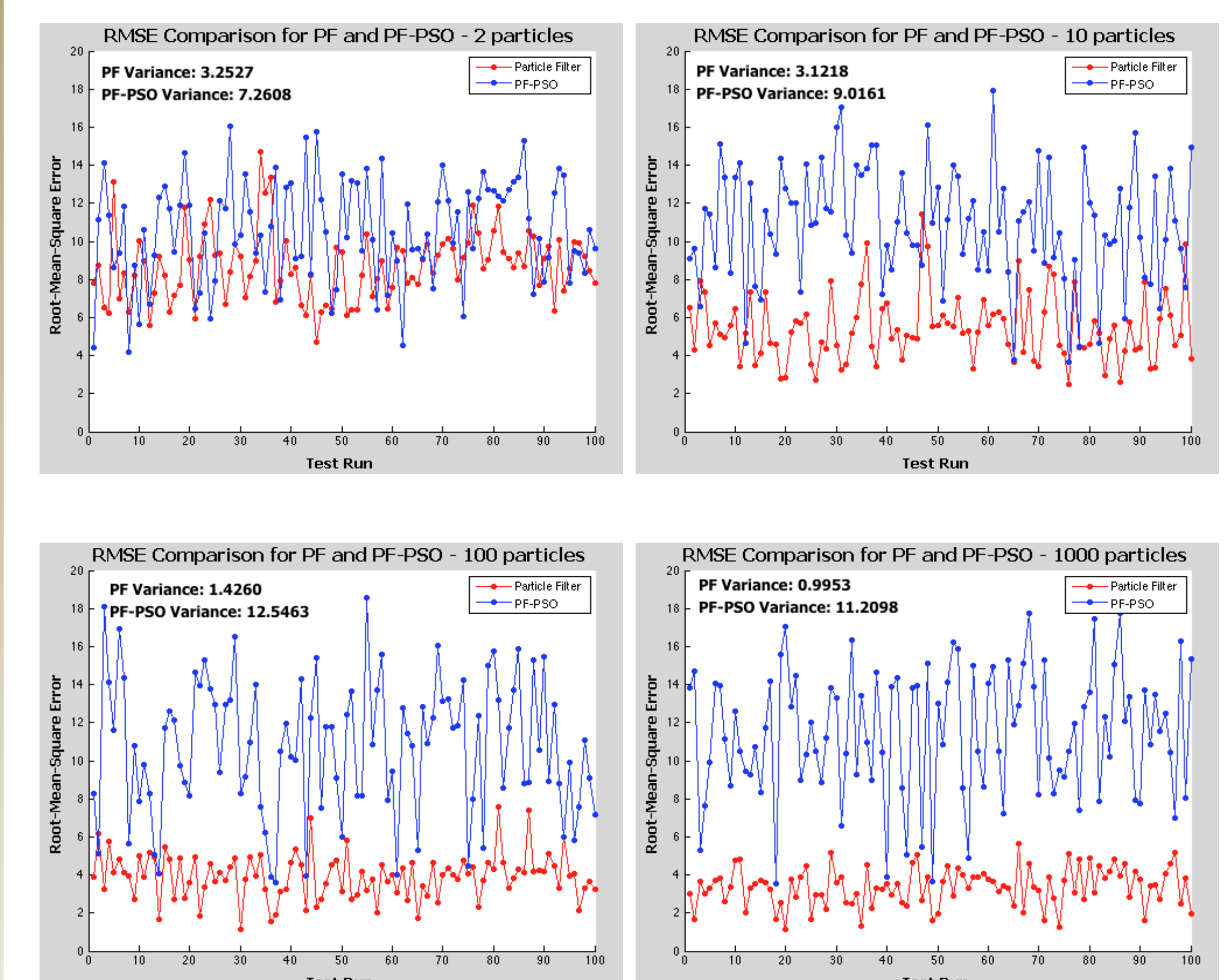
Interactive Data Assimilation Testbed (IDAT)

We developed the Interactive Data Assimilation Testbed (IDAT) in order to expedite the process of testing various data assimilation algorithms. It allows the user to toggle parameter values graphically, minimizing code errors.



Initial Results

The graphs below show the RMS error results from our initial tests on the one-dimensional particle filter and PF-PSO.



Early results indicate that the PF-PSO alleviates particle degeneration, but is not beneficial with respect to efficiency and accuracy. Further research must be done on the PSO in order to better adapt it for use as an auxiliary algorithm.

Acknowledgements

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IDAT was originally designed for use with a 3-dimensional implementation of the Ensemble Kalman Filter (top left). It has since been adapted for use with the classic, 1-dimension particle filter (top right), and has also been configured to run comparison tests between two resampling techniques, SIS and SIR (bottom). We are currently adapting the interface for use with 3-dimensional particle filter and PF-PSO.