# Particle Filtering for Joint Data-Channel Estimation in Fast Fading Channels

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In fast fading channels, the state-of-the-art solution to the equalization problem is represented by the Per-Survivor Processing (PSP) detector, based on the adaptive Maximum Likelihood Sequence Estimation (MLSE) for the joint data-channel estimation. The channel estimation made by Least Mean Squares (LMS) [1], Recursive Least Squares (RLS) [2] or Kalman Filter (KF) [3] algorithms, is incorporated within the trellis of the Viterbi Decoder (VD), which decodes the information symbols.

In this paper, we keep the approach of the joint data-channel estimation used in the PSP detector and we propose a new suboptimal Maximum Likelihood (ML) detection algorithm, based on the Sequential Importance Resampling (SIR) algorithm [5]. The SIR is a sequential Monte Carlo method used in non-linear/non-Gaussian tracking problems. It is based upon point mass or particle representations of probability densities, which can be applied to any state space model and which generalize the traditional Kalman filtering methods. Here, we apply the SIR algorithm to estimate the transmitted data sequence maximizing the a posteriori probability density of the transmitted sequence knowing the received sequence and the estimates of the CIR coefficients. In order to reduce the computational complexity, only a subset of the possible transmitted data sequences are explored using the SIR algorithm. As a consequence, the a posteriori probability density is approximate with a fixed number $N_p$ of particles. This approximation is calculated iteratively by evolving the particles at each instant. Each particle is characterized by a support representing a possible transmitted symbol and a weight related to the likelihood between the support and the true transmitted symbol. The sequence of the supports of one particle named trajectory corresponds to a possible transmitted sequence. Moreover, in order to track the time variations of the CIR coefficients into the data sequence, the CIR coefficients are estimated jointly to the data along each particle trajectory by a KF.

In this application, the state space is discrete and the optimal ML algorithm for data estimation is given using the VD. If the number of particles used by the SIR algorithm is very high, the performance of the Particle Detector (PD) approaches the one of the VD, since it coincides with the exhaustive search. On the other hand, if we reduce the number of particles, the algorithm is suboptimal. Hence, we can use the PD as a complexity reduction algorithm. We have compared the PD with the classical complexity reduction algorithms based on the VD, as the Decision-Feedback Sequence Estimation (DFSE) [4], the M-algorithm [6] and the T-algorithm [7]. For a fixed complexity, we observe that the performance of the PD are close from the one of the classical algorithms. Nevertheless, we can provide different modifications in the evolution scheme of the particles in order to improve the trade-off between performance and computational complexity of the PD. Examples of solutions are proposed in [8] and in [9]. In [8], at each step only the M most likely particles are retained and the others are discarded. We have shown that this solution is equivalent to the M-algorithm. In [9], the state space is explored by groups of particles, which contain a number of particles proportional to the transition probability of the state conditioned by the measures. Using this approach, the computational complexity is adapted according to the signal-to-noise ratio, as in the T algorithm. Moreover, it offers a better trade-off between performance and computational complexity than the first solution, but its performance is to the one of the T algorithm.

We conclude that the application of the SIR algorithm to the digital communications problems in which the unknown state of the model takes its value in a finite set are equivalent to classical complexity reduction algorithms. The papers [8] reaches the same conclusions. Like [8] we believe that the application of the particle filtering becomes interesting in problems where the unknown parameters consist not only of data but also some continuous-valued parameters such as the code delay in the Directed Sequence (DS) spread-spectrum systems for exemple.

## References

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