Title of the tutorial

Analytic Combinatorics for Multi-Object Tracking

Instructors name and affiliation

Dr. Roy Streit – Metron Inc. and University of Massachusetts Dartmouth (Adjunct), USA
Dr. Murat Efe – Ankara University, Turkey
Dr. Blair Angle – Metron Inc.

Abstract

Exact solutions of many problems in tracking have high computational complexity and are impractical for all but the smallest of problems. Practical implementations entail approximation. There is a bewildering variety of established trackers available and practicing engineers and/or researchers often study them almost in isolation of each other without fully understanding what these trackers are about and how they are inter-related. One reason for this is that these filters have different combinatorial problems which are approached by explicitly enumerating the feasible solutions. The enumeration is usually a highly detailed, hard to understand accounting scheme specific to the filter and the details cloud understanding the filter and make it hard to compare different filters. On the other hand, the analytic combinatoric approach presented in this tutorial avoids the heavy accounting burden and provides a solid tool to work with. This tool is the derivative of multivariate calculus, which all engineers easily understand.

This tutorial is designed to facilitate understanding of the classical theory of Analytic Combinatorics (AC) and how to apply it to problems in multi-object tracking. AC is an economical technique for encoding combinatorial problems—without information loss—into the derivatives of a generating function (GF). Exact Bayesian filters derived from the GF avoid the heavy accounting burden required by traditional enumeration methods. Although AC is an established mathematical field, it is not widely known in either the academic engineering community or the practicing data fusion/tracking community. This tutorial lays the groundwork for understanding the methods of AC, starting with the GF for the classical Bayes-Markov filter. From this cornerstone, we derive many established filters (e.g., PDA, JPDA, JIPDA, PHD, CPHD, MultiBernoulli, MHT) with simplicity, economy, and insight. We also show how to use the saddle point method (method of stationary phase) to find low complexity approximations of probability distributions and summary statistics.

Target audience and assumed knowledge

The intended audience is any engineer, Ph.D. student, and interested person working in multi-object tracking and data fusion. The development should be of special interest to individuals working in what is often called random finite sets (or finite point processes), and those working on large problems requiring principled approximations. Open discussion of problems and specific interests are welcome. First course in probability or signal processing would greatly help better grasping the topics covered in the tutorial.