Abstract

We study the problem of hypothesis testing via distributed sampling of a remote Poisson counting process (PCP) source, referred to as the "Distributed Sampling with Centralized Detection (DSCD)" problem. Specifically, we focus on a scenario where one of two PCPs is observed by a set of K remote observers. Each of these source observations is subject to an independent noise. The corrupted observations are then forwarded to a central detector, whose task is to identify the originating PCP source. A key constraint in this setup is the limited capacity for transmitting observations from remote observers to the central detector. This induces a distributed duty-cycle-like constraint: only a subset of time observations, possibly non-contiguous and varying across samplers, may be sampled and transmitted. Although the detector is aware of the sampling profiles, the ON-OFF nature of sampling introduces correlations among the observed segments.

The primary objectives of this thesis are twofold: first, to characterize the optimal performance limits in terms of the error exponent, and second, to design an optimal pair consisting of a distributed sampling strategy and a corresponding detection rule. We focus on two noise models: erasure-type noise, in which some source spikes or events are erased before observation, and insertion-type noise, in which spurious events are added to the source. Assuming arbitrarily high timing resolution, we fully characterize the optimal sampling and detection strategies for both noise models.

We then extend the framework to spatial PCPs and connect it to a detection problem motivated by applications at the Centers for Disease Control (CDC). Building on the high-resolution analysis, we address several practically motivated constraints: (i) limited timing resolution; (ii) the design of optimal and efficient sampling strategies that minimize the number of ON–OFF transitions; and (iii) the characterization of optimal solutions for inhomogeneous Poisson sources with time-varying spiking rates.

Overall, this thesis develops a comprehensive framework for distributed hypothesis testing of spiking sources and provides practical insights into detection under communication and noise constraints.

Keywords: Poisson processes, distributed sampling, detection, scheduling theory, erasure noise, insertion noise, sensing and communication.